THE TOTAL TIME HYPOTHESIS IN AN

AGED POPULATION

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A dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor of
Philosophy in the Department of Psychology
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ABSTRACT

(Psychology-General)

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The familiar adverse effect of fast pacing on verbal learning performance of elderly subjects is reassessed in terms of the Total Time Hypothesis. Forty-five male Ss (ages 60-85) learned three lists of paired associates, each list being presented at a different rate, with total time for learning held constant. In a 3 x 3 factorial design list, rate of presentation and order of list and rate were counterbalanced. With total time held constant, there was no significant effect in performance of rate of stimulus presentation. Had trials been held constant as is customary, there would have been a trend toward better performance at the slower rate. Time as a variable in assessing performance of older subjects was discussed, as was the possibility that pacing is effective by virtue of its influence on task difficulty rather than in its own right.

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Chapter I

INTRODUCTION

Research on learning in the aged has generally shown a deficit in the performance of these subjects as compared with young adults. This comes as no great surprise to anyone, including the old people themselves. Gerontologists of all disciplines, however, are concerned to discover the reasons behind such observed declines; to formulate laws and to define rigorously the circumstances under which such laws operate. The ultimate aim of such work is to ameliorate the problems caused by the decline and to discover means of arresting the process.

The learning deficit of the older person may simply be a part of a generalized decline in functioning after maturity. Why this decline should occur at all is as yet an unanswered question; it appears to be a part of the life cycle of all but the simplest organisms. According to Comfort (1965), the human body is at its most vigorous at age 12, insofar as it is at this age that death from any cause is least likely to occur. Other aspects of the human organism, of course, reach their peaks much later. Nevertheless, after the

decades of the twenties and thirties, most humans will, at best, maintain their levels of performance in virtually any area in question for a while, and then experience gradual decline. Advances in medicine and hygiene over the last century or so have increased remarkably the number of individuals who live out their "allotted spans," but have not appreciably altered the extent of that span. The processes by which people age are little understood, although some progress is being made in specific areas (for instance, research on collagen). The reason(s) people <u>must</u> age may prove to be as fundamental and mysterious as, for example, the question as to what differentiates living from nonliving matter.

Recent investigators have approached the question of decline in the facility of learning itself from a number of different viewpoints. These include:

1. Examining the physiological underlay of the learning deficit (Botwinick & Kornetsky, 1960; Powell, Eisdorfer & Bogdonoff, 1964; Reitan, 1967; Shmavonian & Busse, 1963; Shmavonian, Yarmat & Cohen, 1965).

2. Determining where in the input-mediation-output sequence the deficit originates (Boyarsky, 1968; Eisdorfer, 1967; Szafran, 1965; Welford, 1958).

3. Defining the situations and the types of tasks which contribute to a greater or lesser deficit (e.g., by manipulating task difficulty [Eisdorfer, 1968; Kay, 1955; Szafran, 1953]; by manipulating anxiety level [Eisdorfer, 1963]; by the use of familiar and unfamiliar tasks [Demming & Pressey, 1967]).

4. Studying the uses and effectiveness of various learning strategies (Belbin, 1958; Canestrari, 1964; Eisdorfer, 1968; Korchin & Basowitz, 1956). Other approaches include those which emphasize social factors, especially with regard to society's effect on the older person's expectations for and of himself; and those which emphasize past experience, habitual responses, etc. The study to be described is concerned with variables within the learning situation which affect the subject's performance and, specifically, with pacing.

Chapter II

REVIEW OF THE LITERATURE

Three major factors could conceivably be involved in the observed decline in efficiency of learning in older people. The first of these is accumulated alteration at the cellular level, especially in the CNS, ANS and the circulatory system. The second is the less malleable quality of the older person, which is presumed to result from the accumulation of habits and habitual responses over the years, which may interfere with new learning. Finally, there is the influence of society which, in an era of rapid change, places stresses on the aged both in its generally somewhat derogatory attitude toward them and its demands that they change to suit their defined roles as "old people" in a culture which glorifies youth.

Slowing of Response

Physiology and Psychophysiology

Perhaps the single most ubiquitous finding in the literature on aging is that of slowing of response. There is a fairly large body of evidence on learning which shows the negative effects of fast pacing for aged subjects. Even in the area of autonomic conditioning, old subjects seem, in general, to condition more slowly and to give responses of lesser magnitude than do young subjects. Botwinick and Kornetsky (1960), using a 450 cps tone as CS and mild shock as UCS, found that their older subjects conditioned less readily and extinguished more readily than their younger group. Silverman, Cohen and Shmavonian (1959) measured GSR nonspecifics with tones and spoken phrases as stimuli. With tones, old subjects produced statistically significantly fewer nonspecifics. With spoken phrases, the number of non-specifics was still smaller for old subjects, but the difference was no longer statistically significant. Shmavonian and Busse (1963), in interpreting the above results, considered the old subjects to be generally less responsive than the young but suggested that the meaningfulness of the stimuli (the spoken phrases being more meaningful than the tones) was an important variable. Shmavonian, Yarmat and Cohen (1965) conducted an extensive psychophysiological study wherein they measured plethysmographic, GSR and EEG responses, as well as urinary secretion of adrenaline and noradrenaline. They used tones as CS and strong shock as UCS. Their findings with regard

to vasoconstriction and GSR were in agreement with previous findings--that is, conditioning was slower and responses smaller. They also found, however, that their old subjects produced greater EEG activity in the form of fast (beta) waves, and that the old excreted more urinary adrenaline both before and after the experiment than did young subjects. These latter two findings, although the EEG responses were interpreted as inhibitory (opposed to excitation or arousal), call into question the widely held opinion that the old are, overall, less aroused than the young. Powell, Eisdorfer and Bogdonoff (1964), in a serial learning study, also found evidence suggesting increased arousal in the old in their measurements of free fatty acid levels in the bloodstream.

The above-mentioned studies differ widely in measures taken, tasks to be performed by the subjects, stimuli, meaningfulness of stimuli and, of course, the subjects themselves. In summary, however, they suggest that it is an oversimplification to think of old subjects as simply "less aroused" or "less responsive" than younger ones, although they, in certain ways and according to certain measures, surely are. The EEG and adrenaline data of Shmavonian, Yarmat and Cohen (1965) and the FFA data of Powell, Eisdorfer and Bogdonoff (1964) reveal that the old subjects not only give larger responses, but that these responses continue longer in time than comparable responses in the young groups. Whatever the nature of the "arousal" of which these data are evidence, it does not seem to be the efficient arousal of a fully healthy organism which leads to parsimonious performance of a task.

Shmavonian et al. say, "Apparently the aged organism reacts to a novel and possibly stressful situation with total mobilization of its biochemical defenses by 'giving it all it's got,' whereas the young males react more economically, i.e. by responding to the immediate situation rather than maintained vigil (1965, p. 173)." Powell et al. (1964) interpret their FFA data as indicating anxiety on the part of the old subjects. But here again the experimental situation was more difficult and therefore presumably more stressful for the elderly.

Slowing of response is found in still simpler situations. Surwillo (1968) attempted to trace the slowing of overt responses and found that even speed of transmission in the peripheral nerves shows a decline with age from a maximum of about 58 or 59 meters/second (at about age 10) to about 48-51 meters/second, the decline beginning about age 50. Surwillo refers to work of Waynes and Emmers and of Birren showing synaptic delay in rats which increases "progressively and significantly" with age, and similar delays in neuromuscular latency with voluntary actions. Motor time, or delay between EMG response and mechanical response, does not seem to account for the slowing in aging. The declines in peripheral nerve transmission speed and synaptic delay can account for only 4% and 2% of delay in voluntary actions, suggesting that one look elsewhere for the major causal factors in slowing. The slowing of the alpha rhythm on the EEG was first noticed by Berger in 1933 and was then considered to be associated with pathology (senile dementia). Davis, in 194?, suggested that the alpha slowing was an

age-related change. The "normal" frequency of alpha is 8-13 cps. In young adults, alpha mean is 10.2-10.5. In old persons, alphas of 7 cps and even slower are not infrequently found. Obrist (in Surwillo, 1968) found a mean alpha of 9.1 cps in subjects in a rest home who were in their 60's and 70's and of 8.6 cps in subjects over 80. EEG's in a reaction time experiment produced a correlation of .60 between alpha period (the reciprocal of frequency) and age. Surwillo's own studies found a "statistically significant rank-order correlation of .81 between RT and alpha period in a group of subjects between 18 and 72." This led him to hypothesize that the "period of the alpha rhythm, or some multiple of the alpha cycle, serves as the master timing mechanism in behavior."

Slowing with age has been found in both simple (Botwinick & Thompson, 1967) and choice (Talland, 1968) reaction times. Talland (1965) stated that the delay is primarily associated with the initiation of response. This, among other things, suggests a fundamental cause which is more likely to be central than peripheral.

Learning Studies

In more complex situations than simple autonomic conditioning and reaction time experiments, slowing in the aged is also apparent. Here, whether the immediate question concerns such practical matters as the retraining of old workers (see Welford, 1958, for reports of numerous studies) for changes in the requirements of their jobs, or the theoretical inferences

drawn from laboratory studies of classical learning paradigms, older persons seem to be at a disadvantage compared with younger ones; the more so, the more stringent and obvious are the limitations of time. Fast pacing seems to place greater demands on the old.

Canestrari (1963), in a paired associates study, reported loss of speed with age. He compared young and old subjects under both paced and self-paced conditions and found that, while the older subjects were inferior in performance under both conditions, the paced condition produced a greater difference. Arenberg (1965, 1967) also used a paired associates paradigm with two pacing speeds and found that old subjects responded both more often and more accurately when the longer interval was used. Hulicka et al. (1967), again using paired associate and both paced and self-paced intervals, found that the performances of old (as well as young) subjects improved with unlimited time (self-pacing) for both association and response intervals. Eisdorfer, Axelrod and Wilkie (1963) used a serial learning paradigm and compared old and young subjects over a series of rates. As exposure time increased from 4 sec. to 10 sec. (with 1 sec. off between stimuli), the differences in performance between the old and young groups decreased. Eisdorfer (1965) later did a study to determine whether the extra time needed by old subjects was required for viewing the stimulus. There were four conditions in this experiment; the first compared performance where the stimulus was on for 4 sec. and off for 7 sec., with a 4 sec. on, 1 sec. off condition and found the former to produce more correct responses. The other

two conditions involved a comparison between 4 sec. on, 7 sec. off and 10 sec. on, 1 sec. off. Since old subjects had improved their performance up to the 10-sec. stimulus exposure (but not farther) in earlier studies, the latter situation might be expected to present them with optimum conditions. However, there was no significant difference between 4 sec. on, 7 sec. off and 10 sec. on, 1 sec. off. Eisdorfer interpreted these results as indicating that viewing time per se was not the crucial variable and that the "learning" deficit found in old subjects might well be, rather, a performance deficit.

This hypothesis of Eisdorfer has been shared by other leading investigators in this area, e.g., Arenberg, Canestrari. One major and recurrent finding in the experimental literature which leads toward this view is the preponderance of omission over commission errors in learning studies in the aged. Increased ratios of omission to commission errors with age have been reported by Korchin and Basowitz (1957), Canestrari (1963), Arenberg (1965), Eisdorfer et al. (1963) and Eisdorfer (1965). Arenberg (1965) is quoted by Botwinick (1967): "Poor performance of the old group during fast pacing could not 'be attributed to insufficient time to emit a correctly learned response.'" Eisdorfer's series of studies includes a similar point. In one study, the experimental apparatus made possible the recording of the exact time at which the subject responded. When pacing was moderate, it was found that the old subjects often responded within the time allowed at a faster pace, although they failed to do so at the faster rate. It seemed that the felt pressure of fast pacing might be of more importance than the absolute time

available. In any event, in the Eisdorfer studies the major effect of making the task easier--by whatever means--was to cut down on the errors of omission. Eisdorfer's (1968) summary of his experimental work on aging and learning concluded with a hypothesis which implicated anxiety in the learning situation as an important factor leading both to increased arousal and decreased responsiveness in these subjects. Botwinick (1967) reviewed a number of learning-aging studies. He pointed out that while many of them, as reported above, do suggest a performance deficit, no study has yet ruled out a learning deficit. It seems probable that both exist and that they interact in varying degrees according to the specific demands of a given experiment.

Welford (1957) approached the problem in a somewhat different way and suggested that the major defect in learning facility in the aged is probably involved with short-term memory. Welford offered a listing of seven stages which he felt must be involved before learning, and the evidence that it has occurred, are established. These are:

1. The material must be perceived and comprehended and responding actions selected or built.

2. The material must be held in short-term retention.

3. A durable trace must be established which is capable of remaining relatively unimpaired by subsequent activities of the organism and of standing up to gross depressions of neural activity, such as anaesthetics, drop in temperature, etc.

4. The structural or biochemical changes must endure until time of

recall.

5. There must be recognition of a further situation demanding re-use of the material.

6. The needed material must be recovered from among other material in storage.

7. The recalled material must be used in the new situation in such a way as to produce an overt, communicable response.

Welford suggested that age differences show up especially where the task requires alternation between taking in information for retention and making responses. He felt that the difficulty is in registration (which seems to involve stages 1, 2 and 3 above) and that old people are put at a disadvantage if the pace is too fast, if the signal is too weak, or if the absolute amount to be learned is greater than they can deal with. Experiments by Kay (1951), von Wright (1957) and Belbin (1953) suggest that the old simply cannot learn as much at any one time as the young.

Craik (in Talland, 1968) suggested that the old are at a greater disadvantage in dealing with material which is highly amenable to chunking--the old do not "chunk" as well as the young. This, of course, is quite compatible with the notion that the old cannot learn as much at once--chunking yields a smaller number of items to be dealt with. Craik mentioned dichotic listening studies of Inglis in which STM is also implicated which suggest faster trace decay and greater liability to interference even though the material is initially "as firmly registered in STM for old as young Ss."

Talland (1968) pointed out that the ability to transmit information declines from age 20 to age 70 and stated that the span of immediate recall is most likely to show a deficit if fast pacing and "demanding operations of discrimination and choice" are involved. Talland felt that "the limits of the STR span change with age less than does the probability of performance at the limit of capacity."

Canestrari (1965) mentioned two concepts involved in poor learning in the aged: loss in the ability to register new information and interference from pre-existing habits, both notions assuming degenerative changes in the CNS. Canestrari felt that the reason for the negative effects of fast pacing may lie in momentary lapses of attention in the aged subject. In studies investigating the hypotheses of interference from old habits versus erasure caused by fresh stimulus input, Canestrari's data supported the latter.

It is obvious that, while the learning deficiencies of the aged are well documented and largely agreed upon, the explanations for them are diverse, partial and, sometimes, confusing. What does seem likely is that the older subject is more susceptible to being overwhelmed by the task set before him than the younger person; that anything which makes the task more difficult--in an absolute sense--will make it disproportionately more difficult for the old subject; and that the pressure of fast pacing is one of the most frequently found and extensively investigated of those variables which are known to increase task difficulty.

The Total Time Hypothesis

The total time hypothesis, which has become prominent in the learning literature recently, states in essence that a given amount of material can be learned in a given amount of time, regardless of the number of learning trials into which the material is divided. This hypothesis, which has been substantiated under various circumstances (to be described below), would not be expected to hold for an aged population if time itself, in the form of fast pacing, is a major deterrent to efficient learning (or performance) for these subjects. Therefore, the total time hypothesis seems to provide an effective tool for assessing the effects of time on learning.

The total time hypothesis has not been applied to the study of learning in the aged. It does not always apply even with the young. A review article by Cooper and Pantle (1968) summarizes the work in this area. There are two usual methods of testing TTHo. In the first, total learning time is held constant and different groups of subjects learn at different rates; the number of items correct is then compared among groups. The second method involves, again, different groups of subjects learning at different rates. Here, however, times to criterion are compared. Within these paradigms, under certain conditions, TTHo holds. Paired associates learning has provided the best TTHo conditions--all studies reviewed by Cooper and Pantle where paired associates learning was involved and where stimulus duration was held constant and stimulus-response duration was manipulated supported TTHo. This was not the case where stimulus duration was varied.

Bugelski (1962) used 8 pairs of CVC's[1] as stimulus and response. The

stimulus was always presented for 2 sec. and remained visible while the response syllable was presented for 2, 4, 6, 8 or 15 additional seconds. A 2-sec. inter-item-interval always elapsed before a new syllable appeared. There were five groups of subjects and three random orders of the S-R pairs (to avoid serial learning). Subjects learned to a criterion of two successive correct completions of the list. Bugelski found significant differences in numbers of trials to criterion but no difference in total time to criterion. In terms of trials, the 2 sec.-15 sec.-2 sec. (total item time = 19 sec.) was most successful.

Baumaster and Hawkins (1966) performed a partial replication of Bugelski's study, with some additions of their own. Noting the effectiveness of the 19-sec. total item time (for trials), they varied both S-R duration and inter-item-interval to produce three conditions wherein total item time added to 19 sec. They included two other conditions where total item times were 6 sec. and 11 sec. Stimulus time, as in the Bugelski study, was always 2 sec. Thus, Baumaster and Hawkins had three conditions which replicated three of Bugelski's (in terms of total item time) and two others which yielded a total item time of 19 sec. Subjects were five groups of college undergraduates and criterion was, again, two successive correct completions. Like Bugelski, they found differences in trials to criterion, even among the three conditions where total item time was 19 sec. Nevertheless, they felt that total item time was more crucial than the number of S-R presentations

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1. Consonant-vowel-consonant.

in itself. (Baumaster and Hawkins, like Bugelski, used 8 pairs of CVC's as stimulus and response.)

Nodine (1963, 1965) investigated total learning time, which he defined as trials to criterion X stimulus--stimulus-response exposure time. In the 1963 study, he used 16 pairs of CVC's as S-R items and college students as subjects. Stimulus and response times included all possible combinations of 1/2 sec., 1 sec., 2 sec. and 4 sec., yielding 16 conditions. Each group of 16 subjects learned at ten of the sixteen possible S-R rate combinations. An 8-sec. inter-item-interval was used. The experiment involved, for each group of subjects at each rate, four 5-trial acquisition blocks, each block followed by a recall test trial. All the test trials (where only the stimulus item was presented) used a stimulus duration time of 4 sec. Nodine measured the frequency of correct responses during the recall trials, the mean number of correct responses on the anticipation trials before and after each recall trial, and response latency during recall trials. The 1965 study involved a further investigation of the variables in the PA paradigm, using 16 groups of 5 subjects each, under conditions similar to those in the 1963 study, but with a criterion of 15 out of 16 correct responses (there being 16 CVC pairs) as the primary measure. He summarized the results (and inferences) from both studies in the 1965 paper:

> The present report supplements an earlier investigation concerned with the role of exposure duration of stimulus and response members on the acquisition of a PA list using the anticipation method. Previously, Ss were given a fixed number of learning trials, and exposure durations of stimulus members alone (stimulus duration) and exposure durations of S and R members paired (stimulus-response duration) were found

> directly related to rate of learning. In the present experiment, the effects of independent variations in St, St-R durations were assessed, using TLT as the response measure. TLT refers to trials X exposure time. The values of both St and St-R durations were 1/2 sec., 1 sec., 2 sec. and 4 sec. Stimulus durations were found directly related to TLT, but had a non-significant effect on learning rate when Ss were equated in terms of performance. Conversely, St-R durations were found invariant with respect to TLT, but directly related to learning rate.

At another point in the 1965 paper, Nodine says, ". . . St-R duration is an important determinant of learning rate while St durations beyond 1 sec. inflate TLT without . . . increasing performance."

Johnson (1964) quotes Bugelski as saying that the number of trials times trial duration is fairly constant. Then he describes the hypotheses of his study:

1. If the frequency of exposure is held constant, the amount learned should be an increasing function of time of exposure.

2. If total time of exposure is held constant, the amount learned should be an increasing function of frequency of exposure, given an adequately slow rate of exposure.

3. If rate of exposure becomes too rapid, learning performance should deteriorate.

Johnson used a 4 X 4 factorial design with 15 subjects per cell. TLT was set at 10 sec., 20 sec., 40 sec. or 80 sec., divided into 1, 5, 10 or 20 exposures. "The rate of exposure for each cell is simply the total time of exposure divided by the frequency." Stimulus items were CVC's of 80% meaningfulness and response items, the digits 1 through 8. S and R were

presented simultaneously, separated by a dash, dot and space. There was a 4-sec. intertrial (not inter-item) interval. Subjects were not allowed to respond or verbalize in any way during the learning trials, which were followed by 15 test trials. During the test trials, the stimulus was presented for 4 sec., followed by a 4 sec. blank interval and then the next stimulus. R was never presented during the test trials and the subject's response was never corrected. The score was the number of correct items in 15 test trials. Johnson found total time of exposure significant at < .01; frequency significant at < .05; and the interaction significant also at < .05. There was a significant drop in errors from 1-5 exposures, but no significant change from 5-20 exposures. Unfortunately, in this study, the 4-sec. intertrial interval confounded TLT with distributed practice.

In all, nine PAL studies reviewed by Cooper and Pantle "unconditionally support" the total time hypothesis. Carroll and Burke (1965) and Nodine (1965) indicated that it may not hold where stimulus duration is varied, and Johnson (1964) suggested that perceptual and motivational factors may establish limits on the presentation rate beyond which TTHo does not hold. However, within the general paradigm of PAL, with stimulus duration held constant and within the rather wide limits of 1 sec. and 20 sec. for S-R duration, TTHo is rather firmly established. By the use of this paradigm, we can examine the effects of varying the several members of the total learning task.

In a 1969 article, Cooper (1969) investigated the generality of TTHo in

a study using serial learning. Subjects were 240 college students and 240 fourth-, fifth- and sixth-grade children. All subjects learned a serial list of low-meaningful stimuli by the study-test method, study time being held constant for each trial by varying rate and number of study trials. Three rates (2 sec., 4 sec. and 8 sec. per item) were used. Cooper found that rate had no statistically significant effect on number of correct responses for either group of subjects, with or without overt rehearsal.

Stubin et al. (Stubin, Heimer & Tatz, 1970) considered total time in a paired associates paradigm where S and R were presented simultaneously. Each pair was shown for a total of 20 or 40 seconds, divided into trials of 2, 5, 10, 20 or 40 seconds each. Success was measured by a recall test. Subjects were 135 college undergraduates. The authors found that the amount learned varied directly with total exposure time but (in contrast to Bugelski's definition of TTHo) that more was learned with shorter than with longer exposures per trial, at each total exposure time.

Chapter III

PRELIMINARY STUDIES

Because the TTHo literature is concerned entirely with work done on "normal" (that is, young) subjects, it was necessary to modify the paradigm considerably in order to apply it to the aged. Therefore, two preliminary studies were performed. The first of these used older people as subjects and was designed to determine whether this approach would work at all with this population. Once the changes in the typical TTHo study which seemed necessary to make it feasible as a task for older people were decided upon, a small group of subjects was run. The results of this study will be reported below; however, the paradigm seemed both feasible and adequate. This having been established, another small group of subjects--this time college students recruited from undergraduate courses in psychology--was run on precisely the same task as that used for the older group. The major purpose of this study was to determine whether the revised paradigm (that developed for use with older people) did, in fact, constitute a TTHo study or, in other terms, whether the revised paradigm involved learning in older people which

was of a type consonant with TTHo. The task set for older people was, of course, relatively much easier for the younger subjects; nevertheless, the basic TTHo premises held. These studies will now be described in detail.

Materials and Methods

The majority of TTHo studies in the literature use CVC's as stimuli. Murdock (1965) used A-B pairs of common English words; Sommers (1967) used nonsense syllables of 30% meaningfulness. Murdock's study, however, involved a total length of exposure time of only 4 sec. (divided into one, two or four trials) for each pair of words, and tested for recall of only one of the six pairs learned by each subject. Since it is well known that older subjects do not respond well to stimuli of low or ambiguous meaningfulness, it was felt that CVC's would be inappropriate stimuli for our purposes. Arenberg (although it must be emphasized that he was not testing TTHo) used two consonants as stimuli and two-syllable adjectives as response items. Eisdorfer, in his serial learning studies, used disyllabic nouns as stimuli. Combining the information on stimulus and response items gleaned from the TTHo studies with that from studies designed for use with older people, it was decided to use pairs of consonants as stimulus items and disyllabic nouns as response items.

With regard to time intervals, the TTHo studies utilized a range of

times which easily covers the limits within which older people seem to be able to function. Times for stimulus exposure varied between 1/2 sec. (Nodine, 1965) and 4 sec. (Hall, 1967; Murdock, 1965; Newman, 1964; Nodine, 1965). S-R times varied from 1/2 sec. (Nodine, 1965) to 36 sec. (Sommers, 1967). (These are times per item; that is, the total time for one exposure of an S-R pair.) Comparing these times with those found in the aging-learning literature--particularly the paired associates studies of Arenberg and the serial learning studies of Eisdorfer--a preliminary set of exposure times was selected. In the TTHo literature, incidentally, the interitem interval has not been studied systematically and, in fact (according to Cooper and Pantle), was sometimes a confounding factor. Given these facts, an interitem interval of zero was used in the present study. The stimulus exposure time of 1.9 sec. used by Arenberg as his "fast" time (Arenberg, 1965, 1967) is very close to the 2-sec. stimulus exposure time used by many TTHo investigators. Therefore, 2 sec. was chosen as stimulus exposure time for this study. The Eisdorfer studies on serial learning showed that older subjects improved their performances up to 10 sec. (whether the stimulus word was visible for the entire time or the screen was blank for a portion of the response time) but that lengthening the time beyond 10 sec. did not bring about a further improvement. Therefore, a range of S-R times between 2 sec. and 10 sec. seemed desirable.

It will be remembered that Cooper and Pantle (1968) described two methods usual in TTHo studies--the first keeping total learning time constant and comparing numbers of items correct and the second comparing times

required to reach criterion, by subjects learning at different rates. The first of these seemed more appropriate and more efficient for the subject population to be dealt with in the current studies. This, of course, created further limitations on the time periods to be used in our design.

With the above criteria and limitations in mind, the following design was established:

Three sets of S-R combinations of apparently equal difficulty were devised. Response words, chosen from the Thorndike-Lorge lists, were all within the first two levels of frequency. All response items were disyllabic nouns containing five or six letters. Each S-R list contained five 5-letter nouns and three 6-letter nouns. Pairs of consonants, to serve as stimulus items, were selected to be paired with response words according to the following criteria:

1. Consonant pairs consist of 16 different letters for each list of 8 pairs.

2. No consonant pair is used more than once.

3. Letters in consonant pairs may not be alphabetically adjacent.

4. Familiar abbreviations are excluded (although some scientific or technical abbreviations, such as PB or MV, are included).

5. Consonant pairs which would produce a familiar word with only the addition of an intervening vowel are avoided.

6. Stimulus and response items may not form a larger word when combined.

7. Neither member of a consonant pair is identical to the first letter of its response word.

Each list of S-R items contained eight pairs. The lists are presented below:

A		B		C	
CJ	- WOMAN	DS	- HONEY	XD	- JEWEL
DL	- ROBIN	FC	- VISIT	GS	- UNCLE
KB	- PERSON	TQ	- NOVEL	LF	- PAPER
XH	- SEVEN	MW	- OBJECT	NR	- OCEAN
MV	- ORDER	PB	- STUDY	SP	- HONOR
SQ	- HUMOR	KZ	- SECOND	HC	- SISTER
NF	- DOCTOR	RJ	- FIGURE	WK	- FINISH
TZ	- NATION	NH	- FAVOR	BJ	- REPORT

Stimulus time, as noted above, was set at 2 sec. S-R times were to vary between 2 sec. and 10 sec. Within these limits, various combinations of S (2 sec.) and R times were manipulated. It was found that, if R times of 2 sec., 4 sec. and 6 sec. were used, a total learning time for one set (one list) of 576 sec. would offer three points at which learning could be compared by time--192 sec., 384 sec. and 576 sec. Total item times at the three rates were 4 sec. for 2/2, 6 sec. for 2/4 and 8 sec. for 2/6. Total time per trial (one presentation of the 16 slides which constitute the 8 S-R pairs to be learned), then, was 32 sec. for 2/2, 48 sec. for 2/4 and 64 sec. for 2/6. At rate 2/2, there were 6 trials at 192 sec., 12 trials at 384 sec., 18 trials at 576 sec. At rate 2/4, there were 4 trials at 192 sec., 8 at 384 sec., 12 at 576 sec. At rate 2/6, there were 3 trials at 192 sec., 6 at 384 sec. and 9 at 576 sec. Thus, within this design, we have the opportunity of examining the effects of rate, trials and time at three separate points.

Each "set" of PA pairs was composed of five repetitions of the 8 S-R pairs, randomized to avoid serial learning. This required 80 slides for each set--handily enough, the capacity of a Kodak Carousel slide tray. Using this type of projector, it was possible to continue the presentation of a set of S-R items for the appropriate number of times (determined by the rate) without a break.

A summary of the design follows:

Rate	Trials	Time	Rate	Trials	Time	Rate	Trials	Time
2/2	6	192 sec.	2/2	12	384 sec.	2/2	18	576 sec.
2/4	4	192 sec.	2/4	8	384 sec.	2/4	12	576 sec.
2/6	3	192 sec.	2/6	6	384 sec.	2/6	9	576 sec.

Rates of presentation are designated 2/2, 2/4 and 2/6.

Lists of S-R items are designated A, B and C.

Orders of presentation of each rate-list combination are I, II and III.

This yields nine combinations of rate and list (and 27 combinations of rate, list and order).

ABC/246	BCA/246	CAB/246
ABC/462	BCA/462	CAB/462
ABC/624	BCA/624	CAB/624

Each subject received one of these nine combinations of rate and list, the order in which he received a given set of stimuli at a given rate being

determined by the particular combination he received. Thus, subject "X," receiving combination ABC/246, learned S-R list A at rate 2/2; then, list B at rate 2/4; then, list C at 2/6. Each subject, then, learned each list of stimuli, and he learned each list at a different rate of stimulus presentation. In all, he participated in three learning tasks. The rates, lists and order of presentation were counterbalanced so that the same number of subjects learned a given list at a given rate throughout the paradigm. In the preliminary studies, there was only one subject per combination of list/rate in each group--the older and younger subjects. The full study, done subsequently, included 45 old subjects, yielding 5 subjects to each list/rate combination.

In the TTHo literature, different groups of subjects learned at the different rates. In both the preliminary studies and the full study described here, each subject learned at each rate, thereby serving as his own control.

The stimulus and response items were presented on slides by means of a Kodak Carousel slide projector. The slides were constructed from "rub-on" letters on acetate film, set into slide mounts. The letters used were Stenso brand, made by Dennison Manufacturing Company, and were black, Gothic type, 3/16 inch. Each stimulus slide bore two consonants, centered. The stimulus-response slides bore two consonants, a dash, and the response word. A timing device was designed which allowed for automatic timing of the slide exposures in such a way that alternate slides could be visible for different lengths of time. As mentioned, stimulus exposure time was always 2 sec. S-R exposure time could be set between 2 sec. and 10 sec. In the

case where a subject received the combination ABC/246, for example, where combination A/2 constituted the first learning task, the timer was set to expose each slide for 2 sec. On this subject's second learning task, B/4, the timer was set so that the first slide (DS) was exposed for 2 sec.; the second (DS - HONEY), for 4 sec.; the third (FC), for 2 sec.; the fourth (FC - VISIT), for 4 sec.; and so on. After the full set of 8 S-R pairs (16 slides) had been run through, the pairs appeared again in different order but with the same exposure time per slide. The number of times a given set (8 pairs) of items was seen by the subject depended, of course, on the rate for that task--as indicated under "trials," above. Each learning task was completed when the subject had correctly responded to the sequence of 8 pairs twice in succession, or when the total time of 576 sec. was reached. (Sample scoring sheets appear in Appendix I.)

Results

Study I: Old Subjects

Subjects for this pilot study were recruited from inhabitants of the Durham area. Their names were on file at the Duke Center for Aging, and most of them had been eliminated from participation in other studies for health reasons. Health criteria for this pilot study were minimal--we required only that the subject be able to get around by himself and that he had

neither active heart disease nor known brain damage. From a list of approximately 50 names, we were able to recruit 10 subjects. The data from two of these had to be thrown out due to the subjects' inability to complete the task, leaving 8 subjects. WAIS vocabulary test scores were available on these subjects and ranged between 7 and 13. The age range was 64-76. Subjects were paid $5.00 for their participation. All subjects were male.

Subjects were given the following instructions:

> Mr. ______, I'm going to show you three sets of slides (indicating circular slide tray). This is one set. In each set, the slides are arranged in pairs (removing the first four slides from the tray and showing them to the subject). The first slide in each pair will have two letters on it, like this. The second slide will have the same two letters and a word, like this (indicating the two pairs of slides). Your task will be to learn the word that goes with each set of two letters. You will see these same pairs of slides over and over, although they will not always be in the same order--that is, each letter slide will always be followed by the same letter-and-word slide, but this pair (indicating the first pair of slides removed from the tray) may not always be followed by this (indicating the other slides drawn from tray) one. As soon as you learn the word that goes with a particular set of letters, you should say the word aloud, and you should say it while the slide with only the letters on it is showing. Do you have any questions? (If the subject has questions, they are answered at this time, if relevant to his understanding of the task. If the question concerns something else, it is deferred to the end of the session.) You should try to learn the words as quickly as you can. Are you ready?

After these instructions, the first set of slides was presented. [Most subjects remained slightly confused after the instructions (which are undeniably a bit complex) but soon understood their task quite adequately once the slides began coming on.] Most subjects remarked by about the 18th or 20th slide (9th or 10th pair) that the stimuli were repeating. If by about the end of the third trial the subject had made no response, he was reminded that he

was to say the word aloud and encouraged to try to do so even if he were not absolutely sure he was right.

When the subject had reached criterion or when the 576-sec. learning period was over, the projector and timers were turned off and the slide tray removed. The subject was then given a sheet of paper which contained the letter pairs in one column and the response words in another, and was asked to match them. Below is a sample matching form:

MV	NATION
KB	HUMOR
DL	PERSON
CJ	SEVEN
SQ	WOMAN
TZ	ORDER
XH	ROBIN
NF	DOCTOR

If the subject did not know how to go about matching, it was suggested that he draw lines between the letters and words that went together, or that he write the letters beside the appropriate words, or vice versa. While the subject was performing the matching task, the experimenter placed the next slide tray in position, set the timers, etc. When the subject had finished the matching task, he was told: "That was fine. Now we'll rest a minute and then we'll do another set. You may notice that this time the length of exposure of some of the slides will be different from last time. But your task is exactly the same. Again, try to learn the words as quickly as possible."

After the second set of slides was shown, the subject was informed that there was one more set to do. When this was completed, any relevant ques-

tions the subject had asked during the experimental procedure were answered and the subject was thanked for his cooperation. At all times during the experiment, an effort was made to keep the subject feeling as comfortable as possible. If he remarked on the difficulty of the task, the experimenter agreed that it was, in fact, rather difficult. The subject was assured that the study was not a measure of intelligence and was informed that the area of interest was not how well he performed in an absolute sense nor how he compared with other subjects (a frequent question), but how the changes in exposure time affected his own performance. Most subjects accepted this and seemed to be reassured by it. No formal set of information in this area was prepared since subjects varied considerably in their need for reassurance. The point that the subject was being compared only with himself was made at the beginning of the experiment and reiterated if it seemed necessary. If, after the first set of slides, the subject expressed dissatisfaction with his performance, he was given whatever reassurance was necessary to keep him performing. One subject refused to complete the experiment.

Statistical analysis of results. It should be emphasized that the aim of this pilot study was not to compare young subjects' performance with that of the older ones. The pilot study on old subjects was intended to test the TTHo as a paradigm for use with this age group. The pilot on younger subjects was done simply to be certain that the revised paradigm did, in fact, meet the criteria of a TTHo study. Therefore, statistical analysis was applied to each group separately.

Because the number of possible correct answers to each set of stimuli varied with the rate of stimulus presentation, answers were scored in per cent correct responses--a ratio, in fact, of correct to possible correct answers. This seemed the simplest and most direct way of comparing the individual subject's performance among the three conditions. Throughout, analysis of variance according to Li was used.

<u>Per Cent Correct Responses by Rate</u>

(N = 8; df 2, 21)

at 192 sec.	$F = 3.3$; $p < .10 > .05$
at 384 sec.	$F = 1.7$; NS
at 576 sec.	$F = .71$; NS

At 192 sec., the difference between mean per cent correct responses approaches statistical significance. The difference disappears, however, as the total time increases.

<u>Per Cent Correct Responses by Order</u>

This analysis of variance was done to determine whether the subject was at any significant disadvantage during set I, when he was still learning the task as well as the words.

at 576 sec. $F = .21$; NS

Thus, there was no order effect.

Per Cent Correct Responses by List

This analysis was done to determine whether the lists of stimuli were indeed of equal difficulty.

at 576 sec. $F = .45$; NS

There was no difference among lists.

Per Cent Errors of Commission by Rate

In view of the fact that many investigators have found that the major effect of fast pacing is to increase errors of omission, an analysis of errors by rate of presentation was undertaken.

at 576 sec. $F = .10$; NS

Ratio of omission to commission errors was not affected by rate of stimulus presentation in this paradi gm.

Per Cent Correct Responses on Final Trial by Rate

This analysis was performed on the assumption that the degree of success in learning the response words would be most manifest at the end of each learning task.

$F = .06$; NS

Rate of stimulus presentation did not produce a difference in means on this measure of learning.

Per Cent Correct Responses on Recall by Rate

Recall, measured by a matching task immediately after the original learning of each set, was considered to be yet another means of measuring ultimate success.

$F = .31$; NS

There was no difference in means by this method of measurement.

In summary, the various analyses performed on this data indicated that:

1. there was no order effect.
2. lists of stimuli did not differ in difficulty.
3. with regard to the major variable, rate of presentation,
   a. there was no differential effect on ratio of omission to commission errors.
   b. on three learning measures (per cent correct responses at three separate points during the learning task, per cent correct responses during the final exposure of each sequence of S-R pairs, and per cent correct responses on recall as measured by a matching task), there were no statistically significant differences in performance. Only on per cent correct responses at 192 sec. did the difference in means approach statistical significance.

<u>Study II: Young Subjects</u>

Subjects for this study were recruited by means of sign-up sheets posted in the hall of the Psychology Building. All subjects were students in Duke psychology courses and received experimental credit for their participation. In view of the purpose of the study (to test the paradigm rather than the subjects), no attempt was made to match these subjects with the older group. The task was presented to these subjects just as it was to the older

ones. There were 10 subjects in the young group. As in the older group, all were male subjects.

Statistical analysis of results.

Per Cent Correct Responses by Rate

(N = 10; df 2, 27)

at 192 sec.	F = 1.69; NS
at 384 sec.	F = 1.49; NS
at 576 sec.	F = 1.35; NS

Rate of presentation did not affect performance.

Per Cent Correct Responses by Order

at 576 sec. F = 1.54; NS

There was no order effect.

Per Cent Correct Responses by List

at 576 sec. $F = 5.76$; $p < .01 > .005$

Lists of stimuli are not of equal difficulty for the young subjects. From inspection of the data, it appears that list "b" is more difficult. The words in all three lists were chosen from the Thorndike-Lorge list and were of equal frequency of usage (a and aa). They were assigned randomly to the various experimental lists. In view of the very low F value ($F = .45$) for old subjects, and in view of the absence of any obvious explanation for the list effect, it did not seem necessary to alter the lists. In any event, list rate and order would all be counterbalanced in the main study so that, even if there were a list effect, it would be experienced equally by all subjects.

Per Cent Errors of Commission by Rate

F = .19; NS

Rate of presentation did not affect ratio of omission to commission errors.

Per Cent Correct on Final Trial by Rate

This analysis was not done for young subjects since all of them reached criterion and, therefore, all of them achieved 100% correct R on final trial.

Per Cent Correct Responses on Recall by Rate

Here, too, all young subjects achieved perfect scores. This was the matching task.

Number of Trials to Criterion

This analysis was not done for old subjects since only one of them reached criterion. It was done for young subjects to answer the question as to whether the number of presentations of the stimuli, rather than the total time, had a significant effect on learning/performance. Thus, it is, in effect, another test of the paradigm.

By rate	$F = .35$; NS
By order	$F = 2.67$; NS
By list	$F = 4.6$; $p < .025 > .01$

Here, again, the effect of list appears for young subjects. The other two variables, however, do not appear to affect number of trials to criterion. Thus, this gives a further indication that we are here testing total time rather than some other presentation variable.

Discussion

The two preliminary studies described above seemed to provide evidence that the TTHo method could, indeed, be modified to permit examination of learning variables in an aged population, and that the modified paradigm, as evidenced by its success with the younger group, did, indeed, constitute a total time study. The reasons for performing each statistical analysis and the interpretation of each result are given above. It was decided to proceed with the planned larger study.

Chapter IV

PRESENT STUDY

Subjects

The difficulty of obtaining a large number of older people who had not participated in previous studies, in the Durham area, made it advisable to look elsewhere. The experimenter spoke with the Community Health Association in Charlotte, N. C., which has an active chapter of the American Association of Retired Persons. Mrs. Maribelle Scoggin, who directs community services dealing with old people, was eager to help and provided access to the executive board of the Charlotte Senior Forum, an organization of retired men most of whom have held executive and managerial level positions. The Senior Forum decided to make the study a club project, provided a list of their members and encouraged the members to participate. Mrs. Scoggin and Mrs. C. L. Snoddy also helped the experimenter get in touch with some of the occupants of a local apartment complex for low-income, retired people. Through these two sources, 45 subjects were recruited. These

subjects met the following criteria: male; living in their own homes (that is, not confined to nursing homes, etc.); over 60 years of age; in good health (this criterion included these points: no history of brain damage; no heart or circulatory disease which imposed any serious limitations on their activities; no uncorrected sensory defect or disorder which might interfere with perception of stimuli or ability to respond).

Although it was supposedly established at the time of scheduling that each subject met all these criteria, each subject was specifically questioned on each point before beginning the experimental task. In the event, no subject had to be eliminated for health reasons after arriving for his appointment.

The vocabulary subtest of the WAIS is well known both to correlate highly with the full test score and to hold up well with age; that is, the vocabulary test provides one of the best single indicators of current and of prior level of intellectual functioning as it is measured by this test. It has also been used frequently in the aging literature as an indicator of "IQ." Therefore, this subtest was administered to all subjects as an IQ estimate. The Senior Forum members were, in general, much more willing to participate than were the occupants of the apartment complex. Since they are, generally, above average in "IQ" (and in socioeconomic status), the mean "IQ" of the group of subjects as a whole was somewhat above average. WAIS Vocabulary Scaled Score range for the 45 subjects was 7-17, mean 12.1 (see Fig. 1). Age range was 60-85, mean 69.8 (Fig. 2). Subjects were paid $7.00 for their participation in the study. Senior Forum subjects were not informed that they would be paid until they arrived for their appointments (at the insistence of

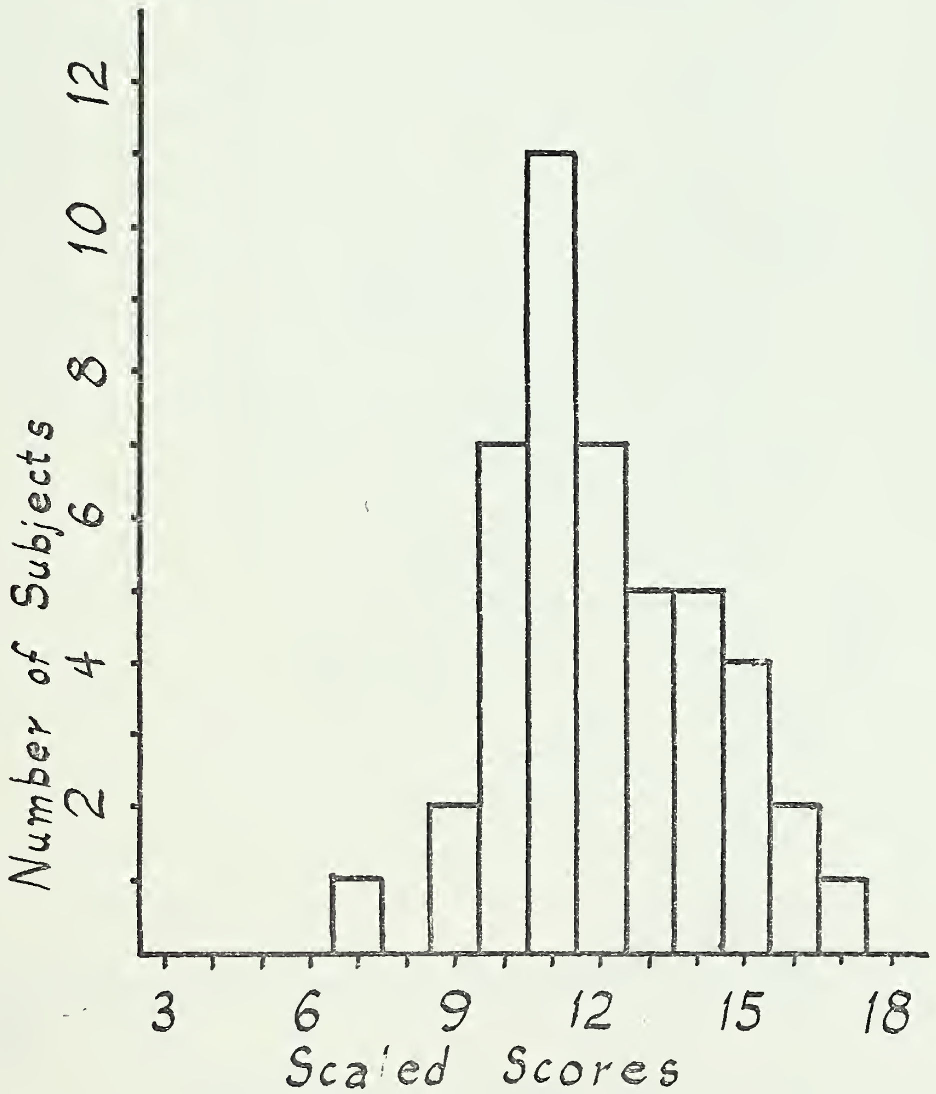

Fig. 1. Distribution of WAIS Vocabulary Scores.

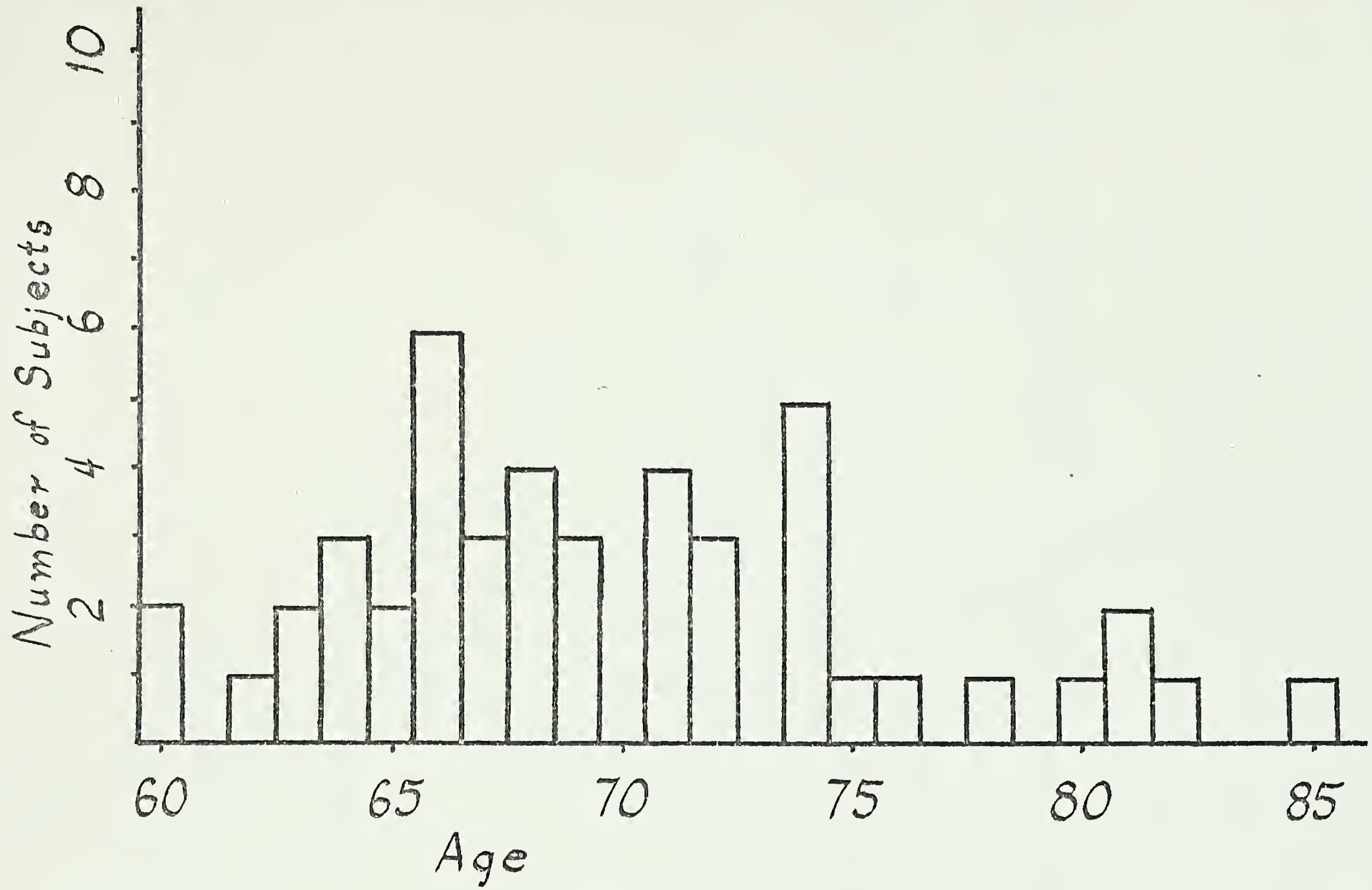

Fig. 2. Distribution of Age.

their executive board). The apartment complex subjects were told during the telephone contact that they would be paid.

Setting

Mrs. Scoggin arranged for the use of the library in the Charlotte United Community Services Building for the experiment. This is a well-lighted, comfortable room in an elegant new building, and is at present rarely used. It was possible to have undisturbed access to this room, and to keep the experimental equipment there, maintaining always the same spatial relationships. The slide projector and timers were placed at one end of a long, empty table, and the slides were shown on a matte finish white wall at the other end of the table. The distance from the projector lens to the wall was 80 in. Each letter, when focused from that distance, was 2 3/4 in. high and 1 1/2 in. wide. The letters showed up dark gray against the white background. All subjects were able to read the slides without difficulty. The subject sat in a comfortable armless but cushioned chair just to the right of the projector so that the distance from the subject's eyes to the wall was also 80 in. (Some subjects, naturally, tended to shift the position of the chair slightly. The variation, however, was small.) All subjects were tested in the same room under the same conditions. The horizontal visual angle was 13 degrees.

Each subject was first asked the necessary questions regarding name, address, social security number and health, and all necessary forms were filled out. This required between five and ten minutes, and was followed immediately by administration of the WAIS Vocabulary test. This required an additional ten to fifteen minutes. Then the formal instructions were given and testing began. The entire procedure (including form-filling and vocabulary test) required between 1 and 1 1/2 hours, the difference depending primarily on the garrulity of the subject and the length of his answers on the vocabulary test. The time spent in the actual testing--that is, the time spent viewing the slides--was just under thirty minutes, including all three tasks.

The equipment, materials, methods and instructions--except for those specific to the full study and described immediately above--were identical to those in the pilot studies.

Statistical Analysis

The statistical analysis of the results of the preliminary studies was done in the simplest possible form--that is, analyses of variance according to Li were done separately for each variable. This is not, of course, entirely statistically legitimate, nor does it give nearly all the information available in the data. Therefore, the full study was analyzed as a standard analysis of variance for a 3 X 3 factorial experiment arranged in nine blocks of

three with each type of block occurring five times. Because of certain mathematical verities of which the experimenter was unaware, the design resulted in eight degrees of freedom being confounded with blocks. These involved two degrees of freedom for each of the interactions Order X List, Order X Rate, List X Rate and Order X List X Rate. The above-mentioned mathematical verities were known to the statistician who aided in the analysis, however, and he found it possible to "unconfound" these interactions. Thus, the 3 X 3 factorial design yields F values for all main effects (Rate, List and Order), and for all the relevant interactions--Order X List, Order X Rate, List X Rate and Order X List X Rate. The statistical analysis also extracts the appropriate error term for the estimable effects which amounts to being the within block treatment combination X subject interaction.

Most of the above-mentioned interactions yielded extremely low F values--many of them were less than 1.0. Interaction effects will not be reported or discussed within the body of the text except in those cases where a statistically significant interaction was found.

Several questions arose after the fact as the data were being studied. It would not be statistically legitimate to perform analyses of variance in these cases. The questions were interesting enough or important enough to require some treatment, however. They will therefore be reported only in terms of mean values and graphs. Within the text, it will be made clear which results derive from the statistically proper full design and which are after-the-fact crude attempts by the experimenter to answer after-the-fact

questions.

The full analysis includes results for main effects and interactions for the following variables: Per Cent Correct Responses at 192 sec., 384 sec. and 576 sec.; Recall; Per Cent Correct Responses on Final Trial (for the sum of the three learning tasks); and Per Cent Errors of Commission. It also includes an analysis by blocks with the scores of "poor learners" deleted, and correlations of scores at 576 sec. with WAIS Vocabulary scores. These correlations yield results not only for the sum of the three scores (by rate) for each subject, but also the within-subject effects.

Results

As in the pilot studies reported above, the major question of interest was the effect of speed of pacing on success in learning lists of paired associates. Again, each subject learned three 8-pair lists (lists A, B and C). A given subject learned each list at a different rate (2/2, 2/4 or 2/6), the rates being counterbalanced so that each rate/list combination was received by an equal number of subjects. There being nine possible rate/list combinations, and 45 subjects in all, there were then five subjects who received each of the nine rate/list combinations. As mentioned above, the order in which a subject learned his three tasks was determined by the rate/list combination he received. (In combination ABC/246, list A was learned first at rate 2/2,

list B second at rate 2/4, list C third at rate 2/6.) Forty-five sets of scoring sheets were prepared, five for each list/rate combination. These were used in the order I through IX, then this order was repeated four more times. Subject "X" received the list/rate combination which was on the top of the stack--perhaps CAB/246. Subject "Y," then, received the next combination, or CAB/462, and so on. Again, only old subjects were included in this study. We were not attempting to compare the performances of old and young. (The TTHo literature gives considerable information with regard to the performance of young subjects on such a task; the preliminary studies show that young subjects perform similarly to old subjects on this particular task but that they are, overall, much better at it.) Therefore, we are considering only the effects of the variables on the performances of aged persons.

As in the preliminary studies, responses were scored in per cent correct of possible correct answers, except where otherwise indicated.

Effects of Rate

Per Cent Correct Responses by Rate

(N = 45; df = 2, 72--Fig. 3)

	2/2	2/4	2/6	F	p
192 sec.	17.9	16.9	12.7	2.55	NS
384 sec.	30.6	31.1	25.3	2.69	NS
576 sec.	39.0	40.5	34.8	2.26	NS

At 192 sec. the interaction OLR (Order X List X Rate) with df 6, 72 yielded an F value of 2.23 $p < .05 > .025$. All other interactions

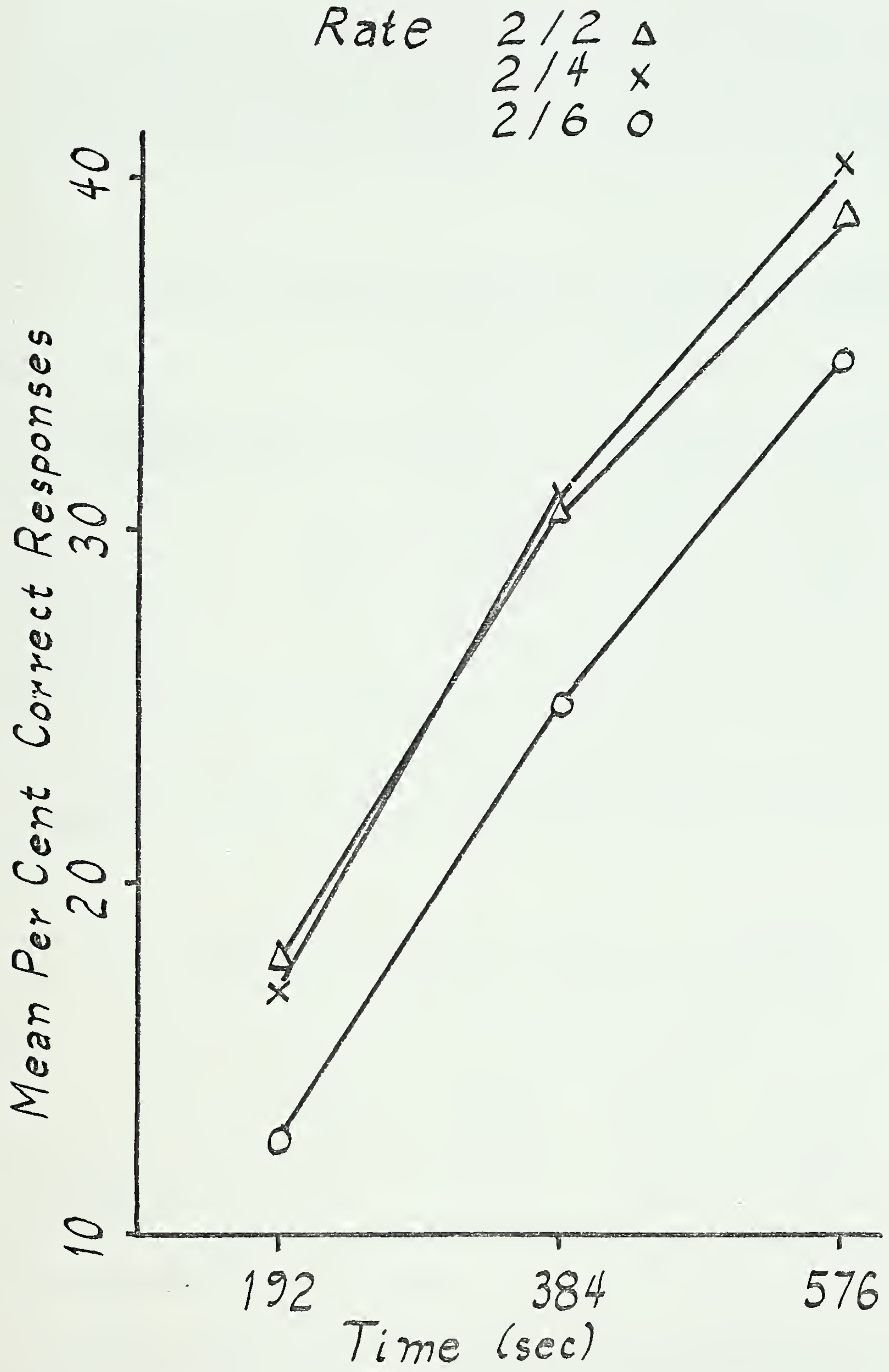

Fig. 3. Mean Per Cent Correct Responses by Rate.

involving rate (Order X Rate, List X Rate) yielded nonsignificant F values, including OLR at 384 sec. and 576 sec.

It is apparent that there is no substantial difference in per cent correct responses according to the various rates. If one looks to the raw figures for trends, rates 2/2 and 2/4 seem to be slightly more effective than rate 2/6 but to differ very little between themselves.

Number of Correct Responses on Final Learning Trial

(N = 45; df = 2, 72--Fig. 4)

(Includes tasks I, II and III.) There being eight pairs of associates to learn, the range of possible correct responses is 1-8.

	2/2	2/4	2/6	F	p
Mean # correct	4.6	4.9	4.4	1.21	NS

No significant interactions.

Rate of exposure has no significant effect on number of correct responses during the final trial.

Number of Correct Responses on Recall

(N = 45; df = 2, 72--Fig. 4)

	2/2	2/4	2/6	F	p
Mean # correct	5.4	5.4	5.9	1.72	NS

No significant interactions.

The number of associates correctly recalled, as measured by the matching task, also yields no significant rate effects. The raw figures here show a superiority of rate 2/6 for the first time. The demands of this task are, of course, somewhat different from those of the learning task itself. Whether the slightly better performance at rate 2/6 is related to the task itself or to the exposure time or is, perhaps, arti-

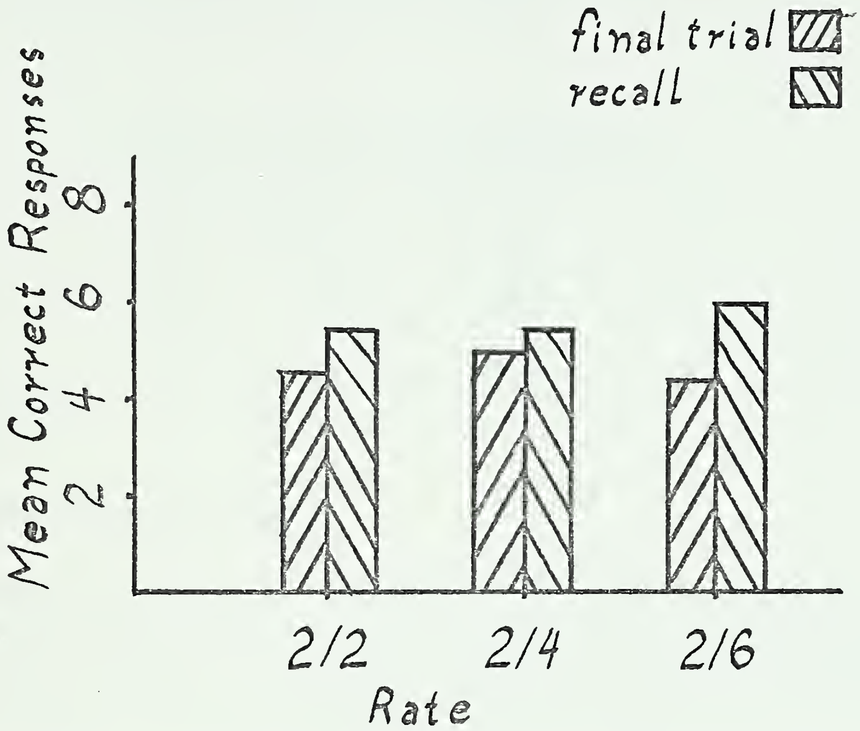

Fig. 4. Mean Correct Responses on Final Learning Trial and on Recall, by Rate.

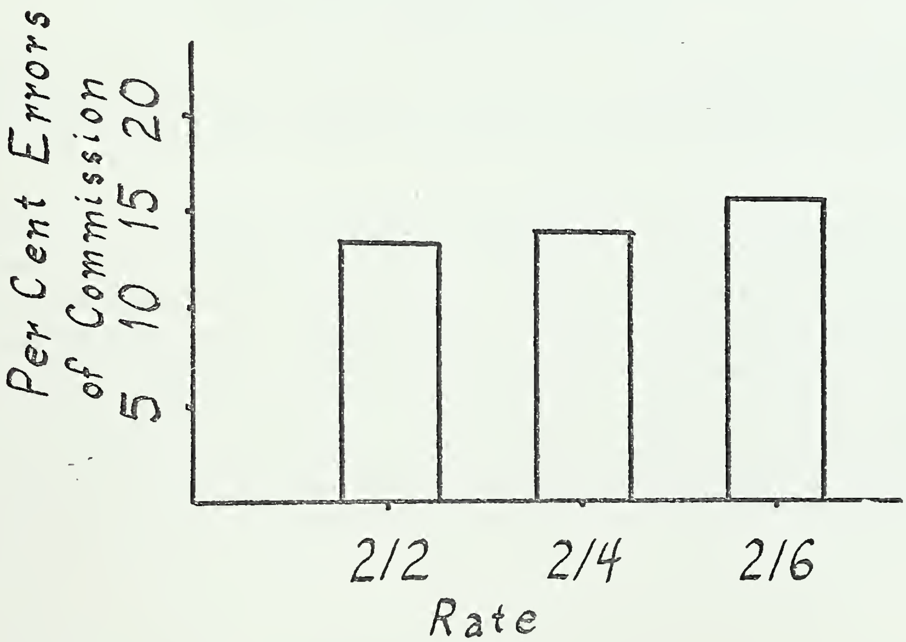

Fig. 5. Mean Per Cent Errors of Commission by Rate.

factual is uncertain. The F value is so low, however, that one would hesitate to interpret this even as a trend.

Per Cent Errors of Commission

(N = 45; df = 2, 72--Fig. 5)

	2/2	2/4	2/6	F	p
Per cent commission errors	13.2	14.2	15.6	.86	NS

No significant interactions.

A higher percentage of commission to omission errors is sometimes assumed to indicate a generally higher level of responsiveness which may, in turn, be related to better performance on learning tasks. In this paradigm, rate of exposure does not appear to produce differences in ratio of commission to omission errors.

Per Cent Correct Responses by Rate for Four and Three Replications

These analyses of variance were done to determine whether the rate of exposure produced different effects for good and poor learners. These analyses were performed in the following way:

Within the design of the full experiment, the 45 subjects were divided among nine blocks of five subjects each. Each block included all the subjects who received a particular rate/list combination. For the analysis for four replications, the subject in each block who achieved the lowest scores was dropped from that block. Similarly, for the analysis for three replications, the two subjects achieving the lowest scores were dropped. Thus, the analysis for four replications includes four subjects per block and thirty-six subjects in all; that for three replications includes three subjects per block and twenty-seven subjects in all.

Analysis for Four Replications

(N = 36; df = 2, 66--Fig. 6)

	2/2	2/4	2/6	F	p
192 sec.	21.2	20.1	14.6	1.85	NS
384 sec.	35.6	35.2	28.0	2.64	NS
576 sec.	45.2	45.6	38.1	2.50	NS

Analysis for Three Replications

(N = 27; df = 2, 48--Fig. 7)

	2/2	2/4	2/6	F	p
192 sec.	22.4	21.0	17.2	.97	NS
384 sec.	37.7	36.9	30.7	1.32	NS
576 sec.	48.2	47.2	40.9	.93	NS

Since all the interactions for the full study were nonsignificant (with the few exceptions noted above), sums of squares for error and interactions were pooled in the present analyses.

Subjects Dropped for Analyses for Four and Three Replications

The analyses for four and three replications, reported immediately above, have shown only very slight differences from that for the full study. The investigator discussed with the statistician the possibility of different patterns of responses among those subjects dropped for these analyses--the "poor" learners. Due to the amount of computer time (and personnel time) already invested in the statistical analysis of this experiment, it did not seem advisable to run analyses of variance for the groups of nine and eighteen subjects, unless some startling differences appeared in their mean scores. The likelihood of finding anything substantially different in the effects of rate on performances among these subjects is remote, in the light of the consistency among results already presented. If there were, in fact, any new patterns, these would be revealed by the means. Therefore, only means will be reported for the poor learners.

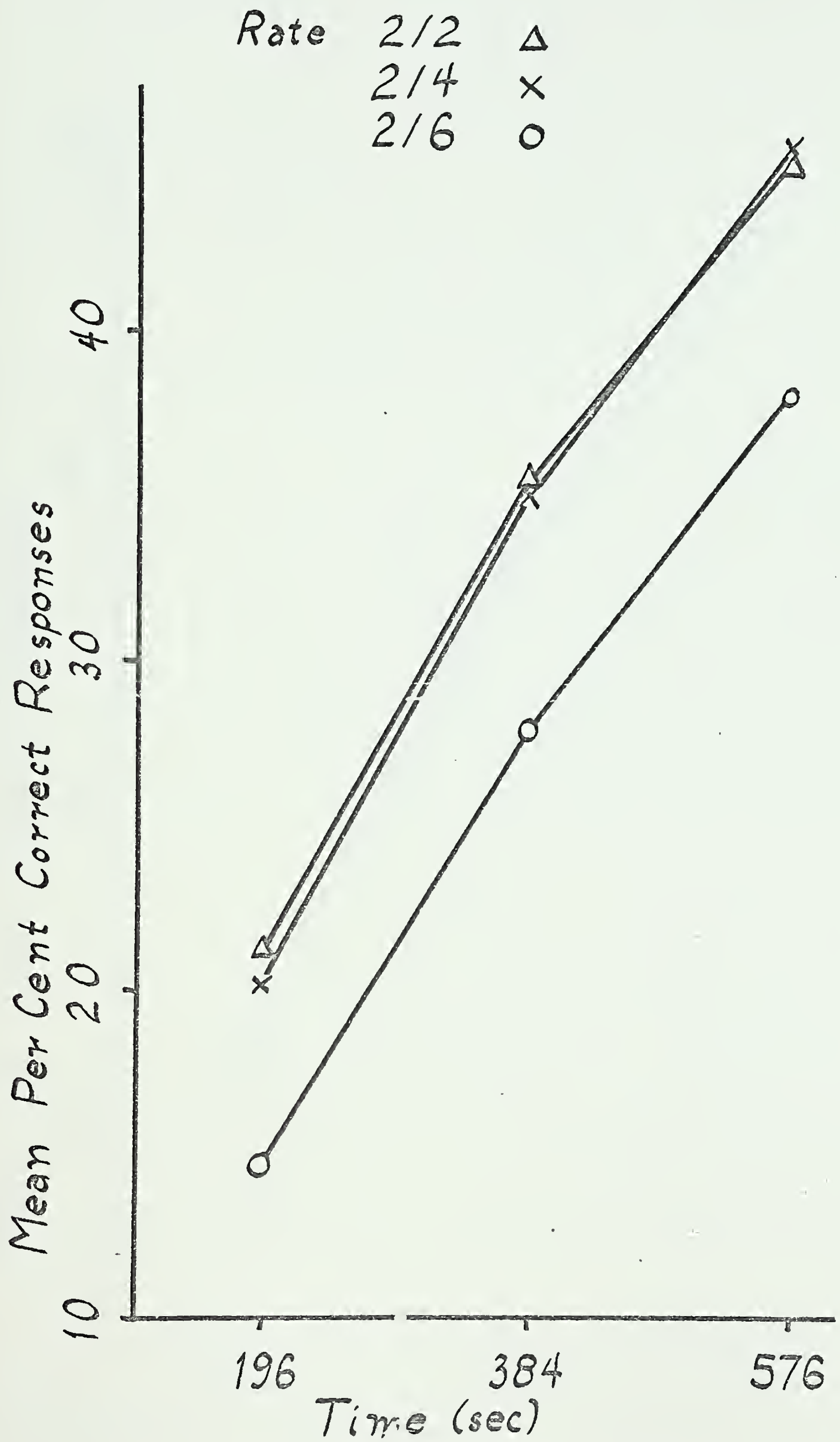

Fig. 6. Mean Per Cent Correct Responses by Rate for Four Replications.

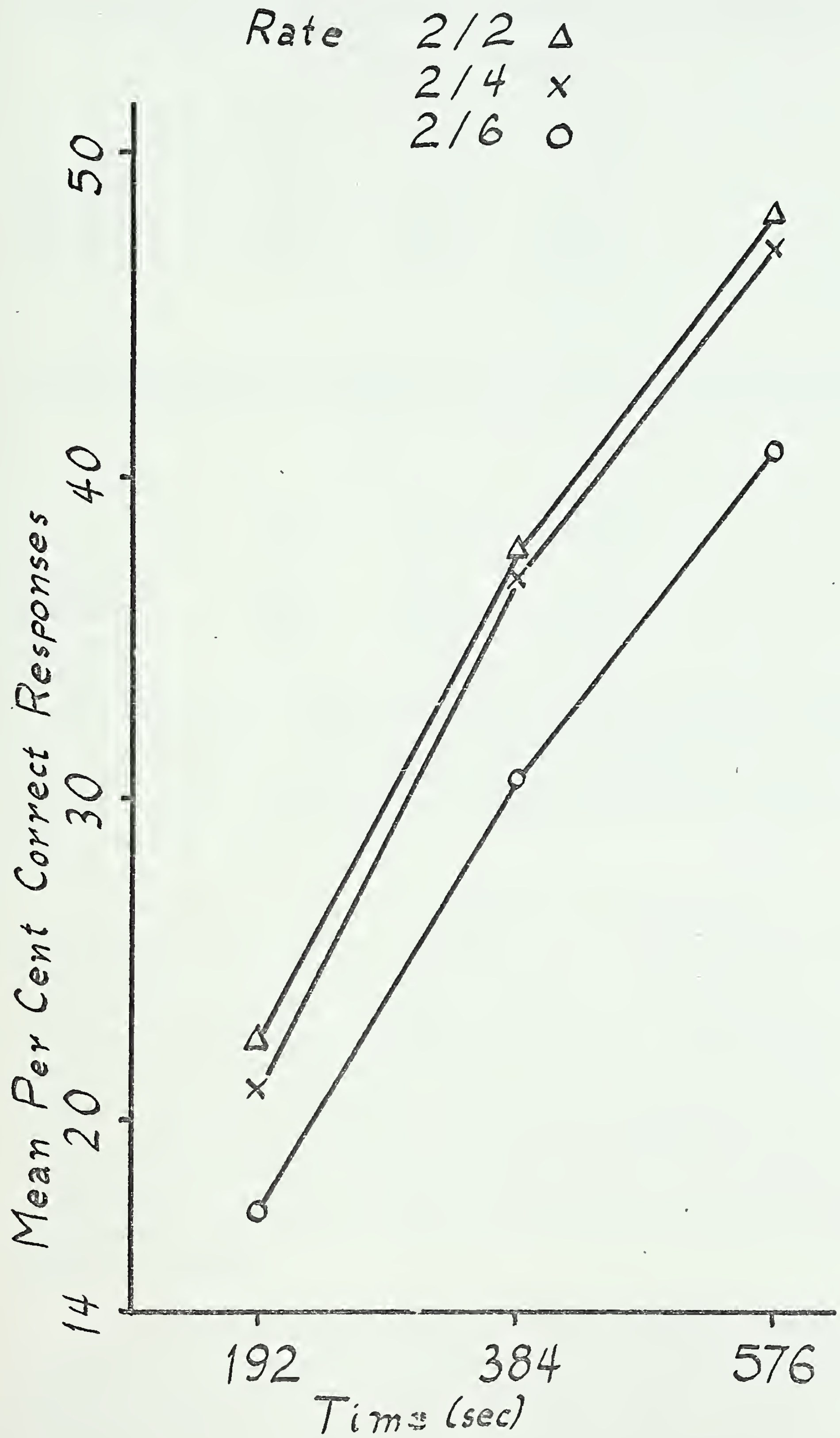

Fig. 7. Mean Per Cent Correct Responses by Rate for Three Replications.

Means for Subjects Dropped for Analysis for Four Replications

(N = 9--Fig. 8)

	2/2	2/4	2/6
192 sec.	5.0	4.2	4.9
384 sec.	10.5	14.5	14.4
576 sec.	14.1	20.2	21.5

Means for Subjects Dropped for Analysis for Three Replications

(N = 18--Fig. 9)

	2/2	2/4	2/6
192 sec.	11.3	10.9	5.9
384 sec.	20.0	22.3	17.1
576 sec.	25.2	30.6	25.6

The means for eighteen subjects include the scores which produced the means for nine subjects. As would be expected, those for nine subjects are lower, overall, since these subjects achieved the poorest scores overall. Similarly, the means for eighteen subjects are lower than those for the full study.

As has been the case throughout the analysis, rate 2/2 seems to produce the best results after 192 sec. For both nine and eighteen subjects, rate 2/4 is superior after 384 sec., while rate 2/6 shows a very slight superiority after 576 sec. for nine subjects; with rate 2/4 still superior at this time for eighteen subjects. The difference at 576 sec. between rates 2/4 and 2/6 for nine subjects is so small as to be disregarded. The only finding of interest among these mean figures is that rate 2/6 does not appear to produce generally inferior results, as it did appear to do for the full study as well as for four and three replications. On the other hand, rate 2/6 does not seem to offer a better opportunity than the other rates for success to "poor" learners, as might be expected.

Comparing the mean figures immediately above with those for the full study, it is apparent that there are no differences great enough to suggest a possibility of statistical significance. The differences among means would have to be larger here than in the results for the full study to produce such an effect, since there are fewer degrees of freedom.

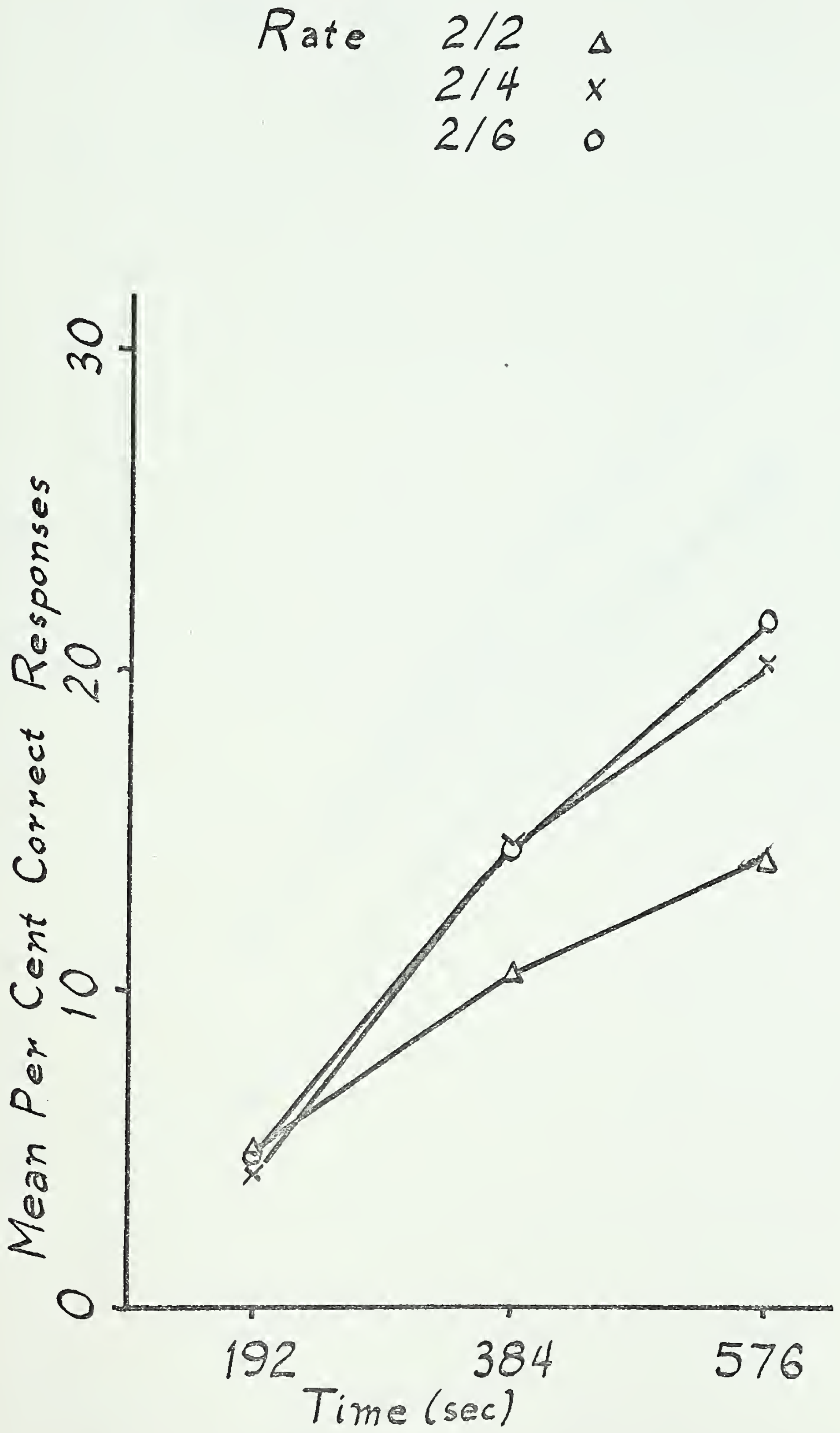

Fig. 8. Mean Per Cent Correct Responses by Rate for Nine "Poor Learners."

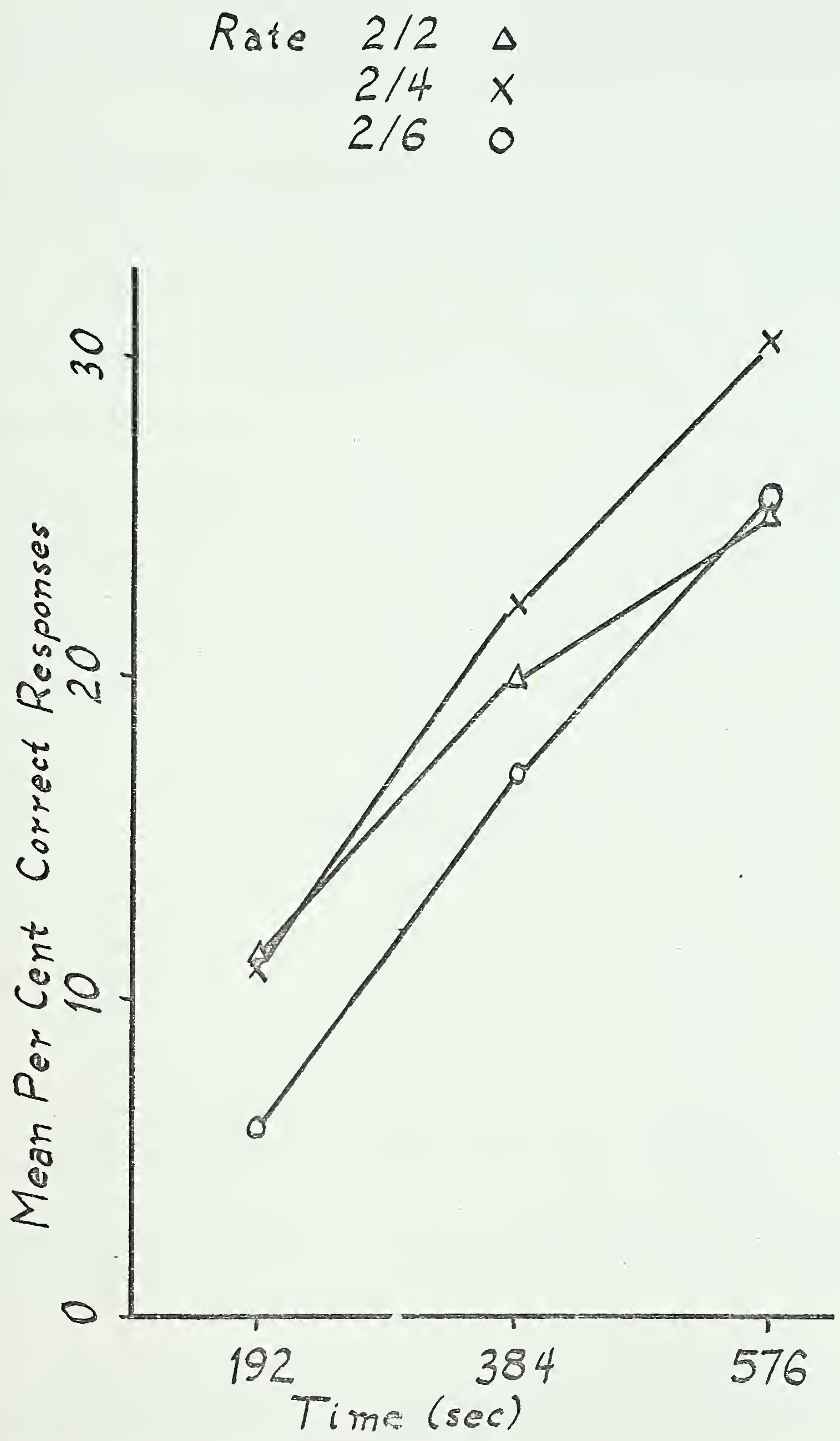

Fig. 9. Mean Per Cent Correct Responses by Rate for Eighteen "Poor Learners."

With this in mind, it would be well to interpret these differences among means with considerable caution. There is nothing in these figures which is outstanding enough even to suggest the strong possibility of a trend.

Correlations. Two nonparametric correlations were run between WAIS vocabulary scores and performance in per cent correct responses after 576 sec. The statistics used were Kendall's Tau and Spearman's Rho. Rho is more familiar to psychologists than is Tau. Tau, however, is sounder mathematically and provides a more precise tool for discerning the effects of the type of relationship with which we are here concerned. The two statistics yielded results which are identical except for significance level. Correlations were performed for the three rates, 2/2, 2/4 and 2/6 and for the pooled scores for each subject.

Results of Correlations

Rate	Rho	Tau
2/2	.53 $p < .01$	.39 $p < .05$
2/4	.53 $p < .01$	.39 $p < .05$
2/6	.48 $p < .01$	.34 $p < .05$
Total	.59 $p < .01$	.43 $p < .05$

As would be expected, IQ as measured by the WAIS vocabulary test correlates positively and significantly with successful performance at all three rates and for the pooled total. The correlation coefficients at each rate are very similar. The coefficients for "Total" would be expected to be higher than those for each rate, since they are computed from figures which pool the performance at each rate, and each of the rate coefficients is positive.

In view of the importance of the question of the relationship between "IQ" and performance at the various rates, the most revealing finding among the correlations is that WAIS vocabulary score correlates posi-

tively with all three rates, with no substantial differences among rates. The correlation coefficient for rate 2/6 is, according to both statistics, somewhat lower (although not statistically significantly lower) than those for rates 2/2 and 2/4. If this can be interpreted as indicating anything at all, it is that rate 2/6 is less closely related to "IQ" than the other rates. It has been shown in the results reported above that rate 2/6 is slightly inferior in nearly all cases, but less so among "poor" learners. This is consistent with the correlation results.

As mentioned above, several questions arose after the fact which could not, for reasons of statistical validity, be treated within the analyses performed on the full design. These questions concerned effects of rate upon performance on Task I, comparison of subjects who achieved high and low WAIS vocabulary scores, and performances by subjects who reached criterion on one or more tasks. These questions are treated here only by comparison of means, and by graphs.

Per Cent Correct Responses by Rate on Task I

(N = 15--Fig. 10)

The rationale for this analysis is the fact that during Task I the subject is learning not only the P-A pairs but also the task itself. It seemed that there might be differential effects of rate under this "learning to learn" condition. There being 45 subjects in all, there are 15 subjects in each rate group--that is, 15 subjects learned first at rate 2/2, 15 at rate 2/4 and 15 at rate 2/6. The lists were similarly counterbalanced but are not of specific interest here.

	2/2	2/4	2/6
192 sec.	18.0	12.8	13.8
384 sec.	28.2	21.4	26.7
576 sec.	35.6	29.2	35.0

Here we see a trend toward superiority of rate 2/2, especially after 192 sec., with virtually no difference between rates 2/2 and 2/6 by the

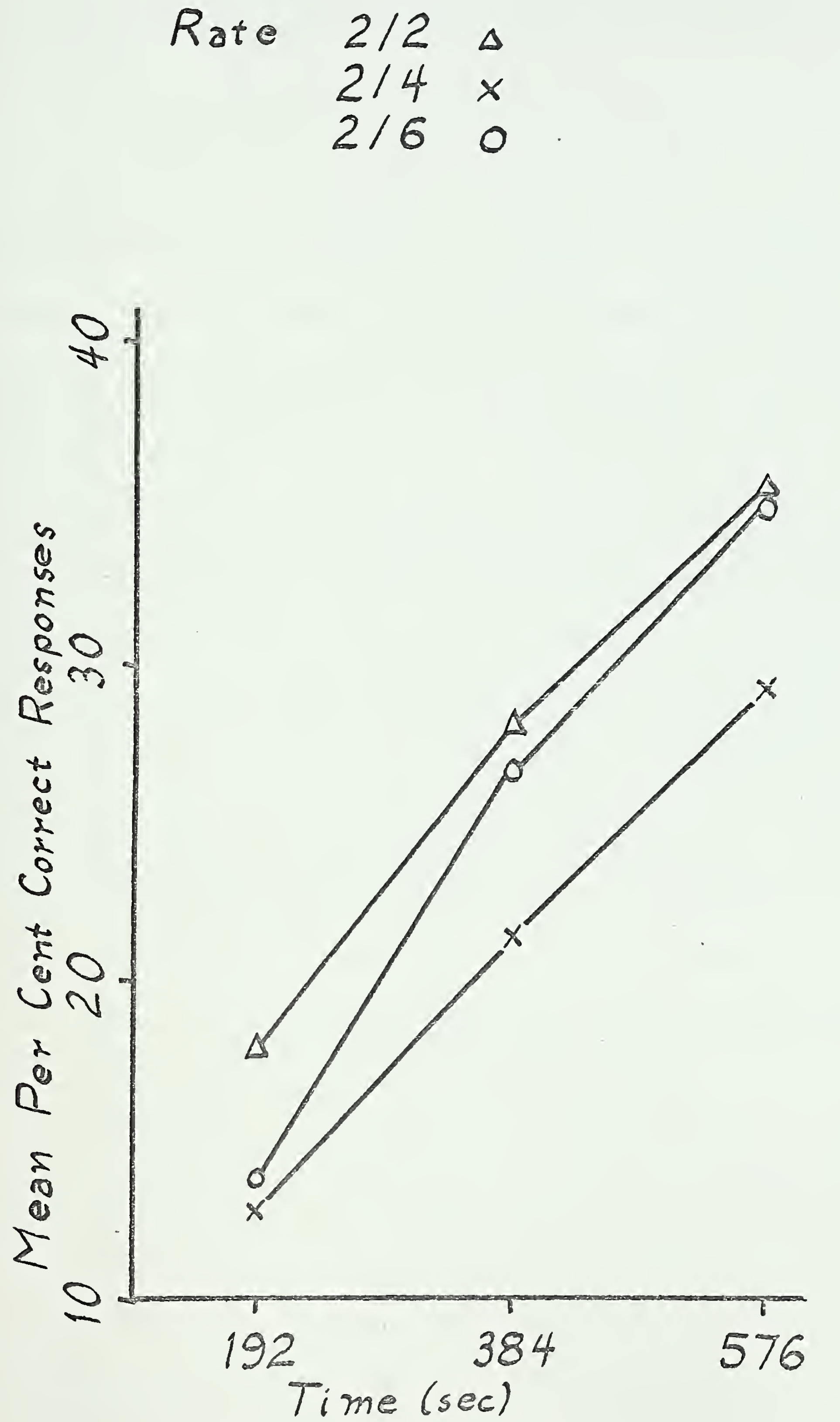

Fig. 10. Mean Per Cent Correct Responses by Rate on Task I.

end of the task. Rate 2/4 offers the poorest results for Task I. It is unlikely, however, that any of these differences would be statistically significant.

Since the group of forty-five subjects recruited for this study achieved a mean WAIS vocabulary score of 12.1, which is considerably above average, it was thought worthwhile to examine the effects of "IQ" in as many ways as were feasible. The correlations reported above showed that "IQ" correlated positively with high per cent correct scores at all rates, and that there was very little difference in the correlation coefficient among rates. The analysis of variance for four replications showed no differential effect of rate among the more successful subjects. In order to approach the problem from still another direction, the subjects were divided into two groups by WAIS vocabulary scores, and the mean per cent correct responses calculated separately for these two groups. The median score on the WAIS vocabulary test falls in the middle of Scaled Score 12. There seemed no valid way of separating subjects who achieved a scaled score of 12, and it was impossible to produce two groups of the same number of subjects because the total group was an uneven number. Therefore, the subjects were divided into groups scoring 12 and above (N = 24) and 11 and below (N = 21).

Per Cent Correct Responses by Rate--
WV Scores 12 and Above

(N = 24--Fig. 11)

	2/2	2/4	2/6
192 sec.	23.2	23.6	18.0
384 sec.	38.3	40.3	32.5
576 sec.	49.1	51.7	42.5

Per Cent Correct Responses by Rate--
WV Scores 11 and Below

(N = 21--Fig. 12)

	2/2	2/4	2/6
192 sec.	11.9	9.3	6.6
384 sec.	21.8	20.6	17.0
576 sec.	27.4	27.8	25.9

At 192 sec., rate 2/4 shows a very slight superiority for the high "IQ" subjects, and rate 2/2, a slight superiority for low "IQ" subjects. This pattern recurs at 384 sec. At 576 sec., at the end of the task, rate 2/4 is best for both groups. Rate 2/6 appears to offer inferior results overall, but especially for low "IQ" subjects after 192 sec. and for high "IQ" subjects after 576 sec.

Subjects Who Reached Criterion

According to the design of the study, each learning task was considered completed when the subject had utilized the full time of 576 sec. or when a criterion of two successive completions of the list of eight associates was achieved. Of a possible total of 135 such successes, there were 28 cases wherein criterion was reached. These cases were produced by 17 subjects; 8 subjects reached criterion on one task, 7 on two tasks, and 2 on all three tasks. The rates, lists and orders involved in these successful tasks are listed below:

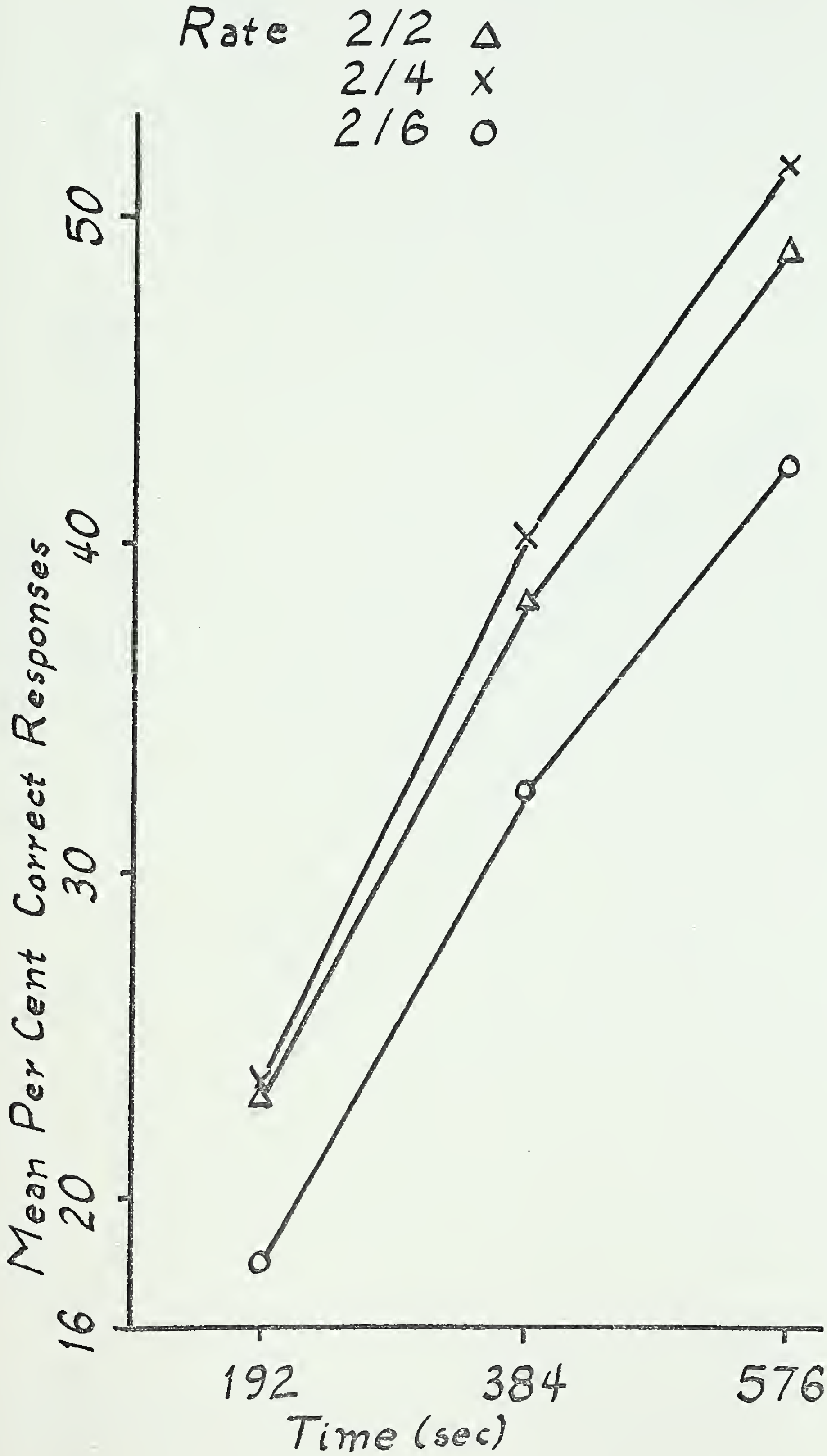

Fig. 11. Mean Per Cent Correct Responses by Rate--WAIS Vocabulary Scores Twelve and Above.

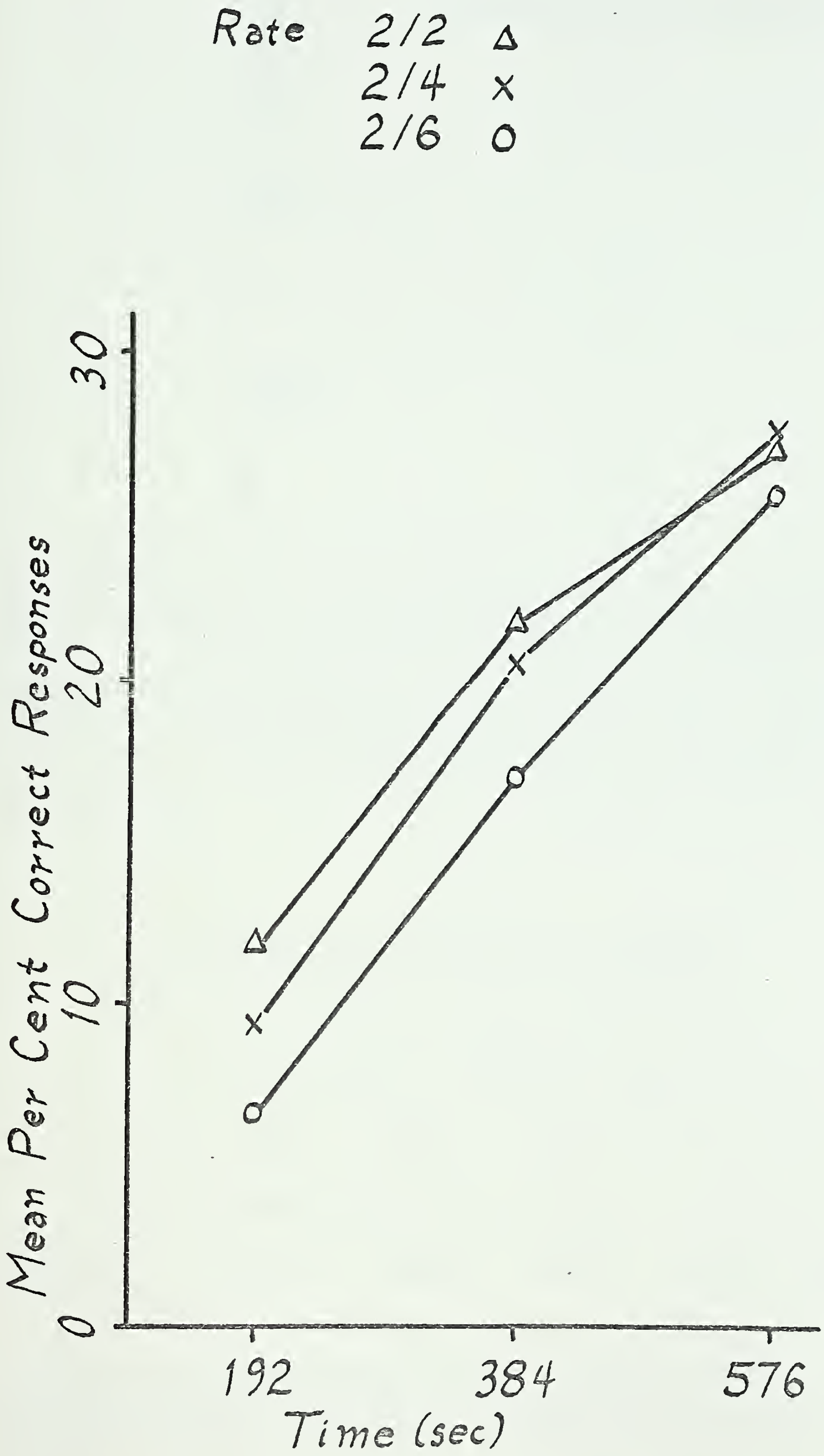

Fig. 12. Mean Per Cent Correct Responses by Rate--WAIS Vocabulary Scores Eleven and Below.

Rate	Subjects Reaching Criterion
2/2	12
2/4	11
2/6	5
Lists	
A	12
B	3
C	13
Order	
I	7
II	13
III	8

Since these 28 cases and 17 subjects constitute, in effect, a special class, an analysis of variance was run for results by rate. It must be pointed out that the results of this analysis do not have the statistical legitimacy of those analyses performed for the full design, and that the results must be interpreted with care. The analyses were performed on the variables "mean time in seconds to criterion" and "mean trials to criterion." Analysis of variance for unequal numbers, according to Li, was used.

Tasks Wherein Criterion Was Reached

Analysis of Variance for Unequal Numbers, Li

(T = 28; df = 2, 25--Fig. 13)

	2/2 (N = 12)	2/4 (N = 11)	2/6 (N = 5)	F	p
Mean time in seconds	413.3	484.4	537.6	3.54	$<.05>.01$

Statistical analysis here reveals a significant difference among means in seconds to criterion. Looking at the raw figures above, it is obvious that rates 2/2 and 2/4 produced very little difference in

numbers of successful completions of the task, whereas rate 2/6 produced less than half the absolute number of successes as either of the other rates. According to the Total Time Hypothesis, one would expect to find no statistically significant difference in time to criterion, although a difference in trials to criterion would be expected. Given the fact that the number of seconds required to complete one trial varies with rate (being 32 sec. for rate 2/2, 48 sec. for rate 2/4, and 64 sec. for rate 2/6), it was decided to subtract the number of seconds for one trial from each "mean time in seconds" listed above. The rationale for this procedure is that the first successful completion of the list indicates that it has been learned, while the second completion merely provides a check. This check is obviously necessary; however, the time it involves is not necessarily truly learning time. Subtracting the time for one trial at each rate yields the following analysis:

Analysis of Variance for Unequal Numbers, Li

(T = 28; df = 2, 25--Fig. 13)

	2/2 (N = 12)	2/4 (N = 11)	2/6 (N = 5)	F	p
Mean time in seconds	381.3	436.4	473.6	2.00	NS

When the time for the final or "check" trial is subtracted from the means, the statistically significant F value disappears.

Trials to Criterion

Analysis of Variance for Unequal Numbers, Li

(T = 28; df = 2, 25--Fig. 14)

	2/2 (N = 12)	2/4 (N = 11)	2/6 (N = 5)	F	p
Mean # of trials	12.9	10.1	8.4	7.01	< .005

Trials to criterion, as expected, produces a highly significant F value.

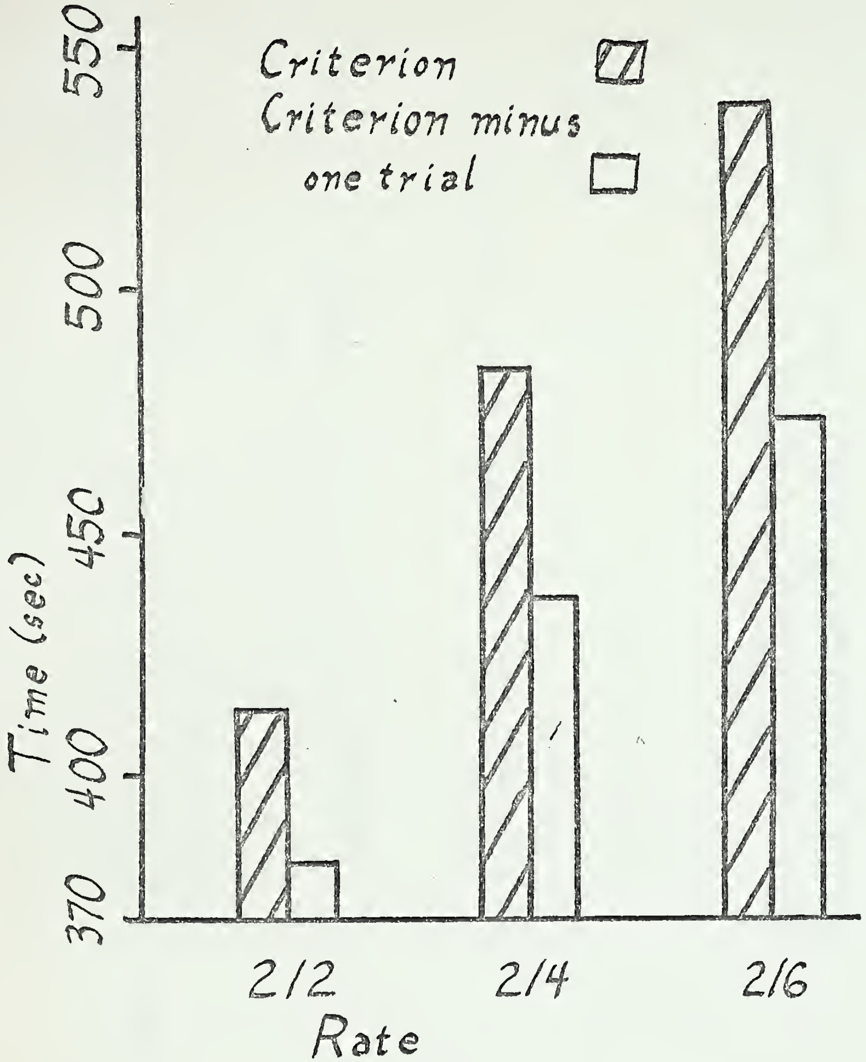

Fig.13. Mean Time to Criterion in Seconds, by Rate.

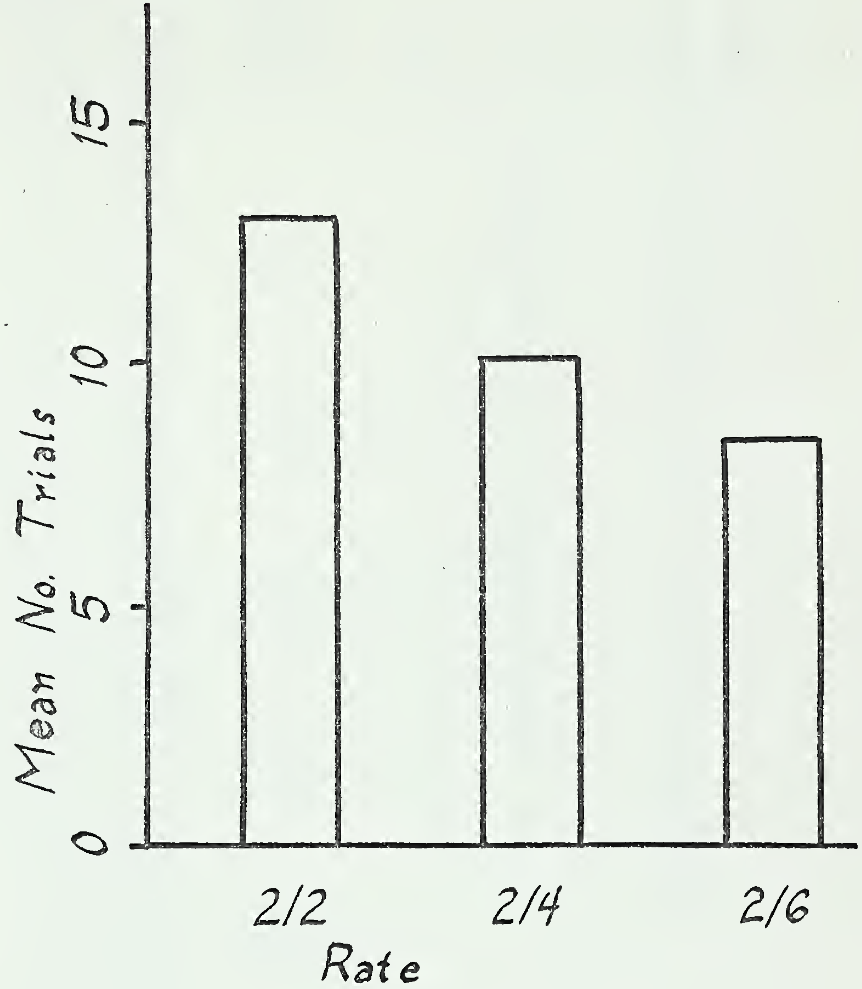

Fig. 14. Mean Trials to Criterion by Rate.

Effects of List

The effects of the variable, "list," were also investigated.

Per Cent Correct Responses by List

(N = 45; df = 2, 72--Fig. 15)

	A	B	C	F	p
192 sec.	18.3	10.9	18.3	5.96	< .005
384 sec.	32.8	19.6	34.5	17.22	< .005
576 sec.	42.3	27.7	44.2	20.41	< .005

Clearly, the list effect suggested in the data for young subjects in the preliminary studies has proven itself to be more than an artifact. List is highly significant at each time. Inspection of the means indicates that list B is considerably more difficult than either of the other lists, whereas lists A and C differ only very slightly.

Number Correct on Final Learning Trial, by List

(N = 45; df = 2, 72--Fig. 16)

	A	B	C	F	p
Mean # correct	4.7	3.9	5.3	11.84	< .005

This F value, too, is significant beyond the .01 level.

Number Correct on Recall, by List

(N = 45; df = 2, 72--Fig. 16)

	A	B	C	F	p
Mean # correct	5.7	4.9	5.9	6.18	< .005

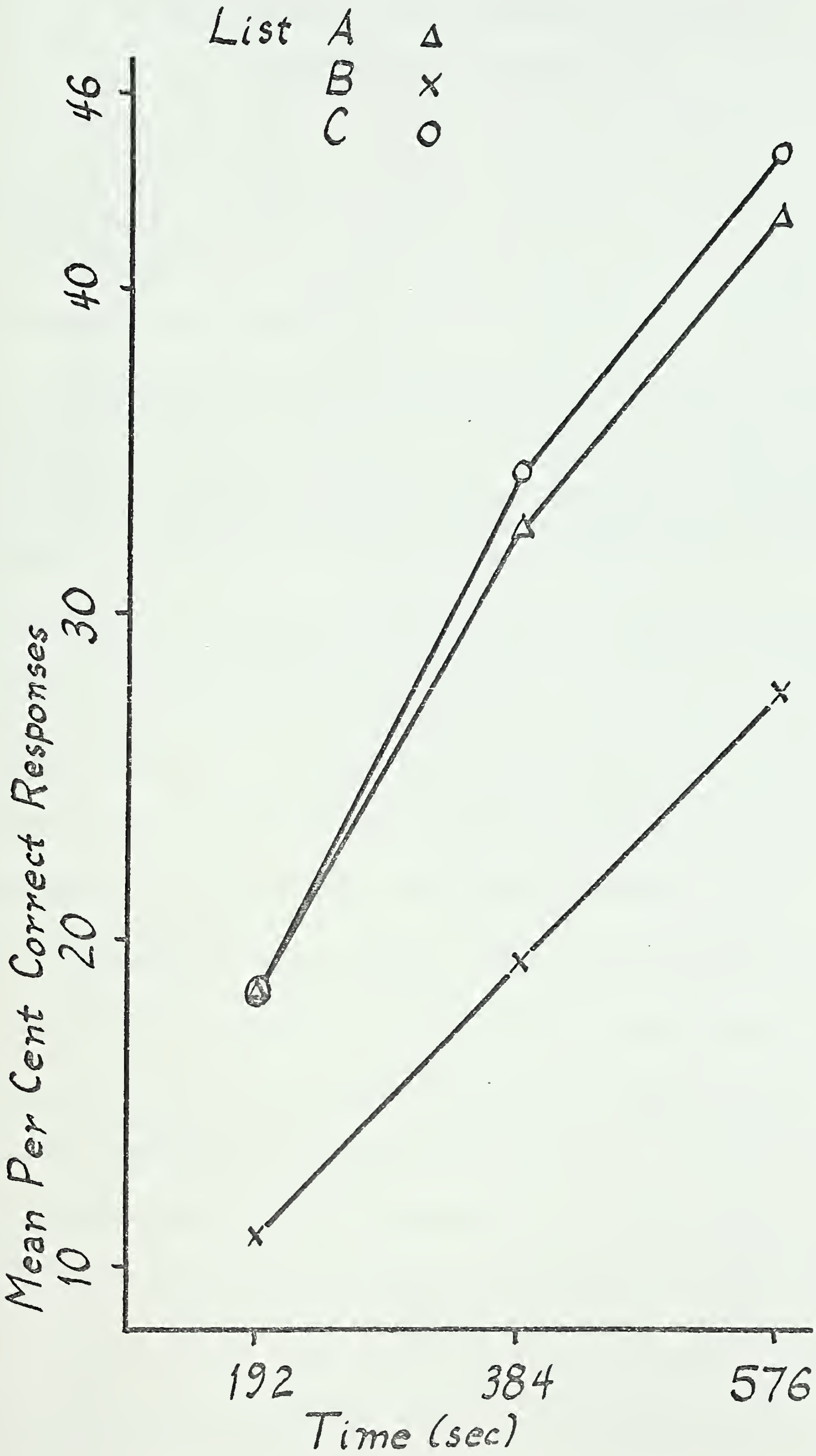

Fig. 15. Mean Per Cent Correct Responses, by List.

Per Cent Errors of Commission, by List

(N = 45; df = 2, 72--Fig. 17)

	A	B	C	F	p
Mean % errors of commission	14.2	11.7	17.5	4.16	< .025 > .01

No significant interactions.

This comparison is interesting because it shows that the difficulty of the particular list may affect the type of error made. Although the list effect is somewhat less here than elsewhere, it is still significant at beyond the .025 level. This finding may tend to support the notion that errors of commission are related to responsivity, and that responsivity is related to the difficulty of the material.

The finding of significant effects of list is ubiquitous throughout these data. Since the counterbalancing built into the design provided for each subject to experience the list effect equally and, especially, since no significant interactions occur in any of these analyses, it can be stated with some assurance that the list effect did not differentially affect subjects.

The magnitude of the list effect was greater than had been anticipated, even considering the appearance of a list effect among young subjects in the preliminary studies. The manner in which the response words and stimulus letters were selected has already been described. It was noted that the words were all of A or AA frequency according to the Thorndike-Lorge list, and that each list contained equal numbers of five- and six-letter words. Inspection of the words in each list fails to reveal any obvious suggestions as to the reason(s) for the difficulty of list B. Therefore, attention was

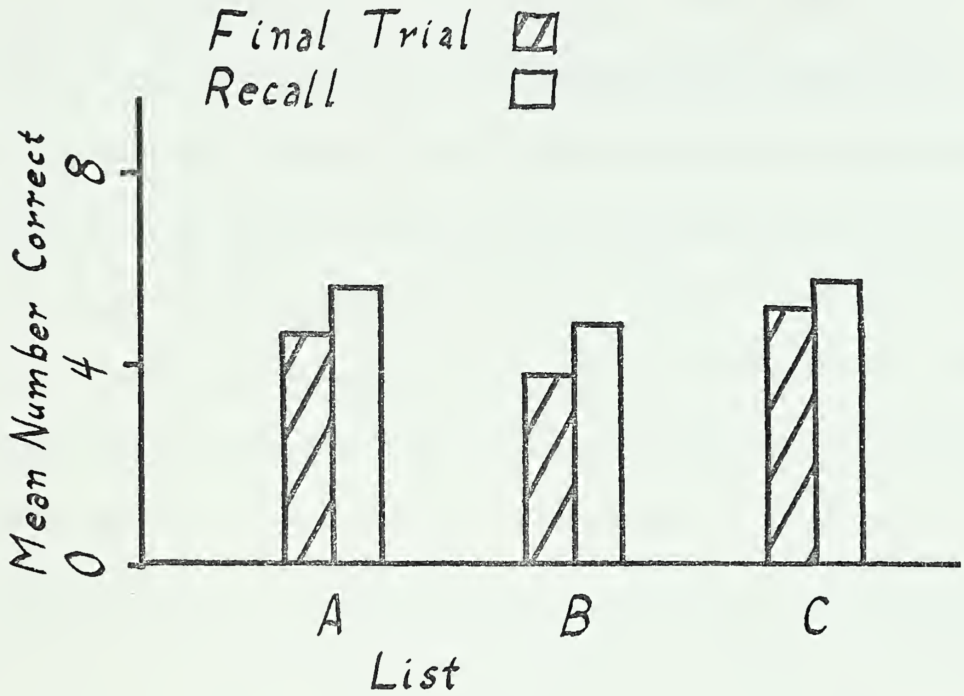

Fig. 16. Mean Correct Responses on Final Learning Trial and on Recall, by List.

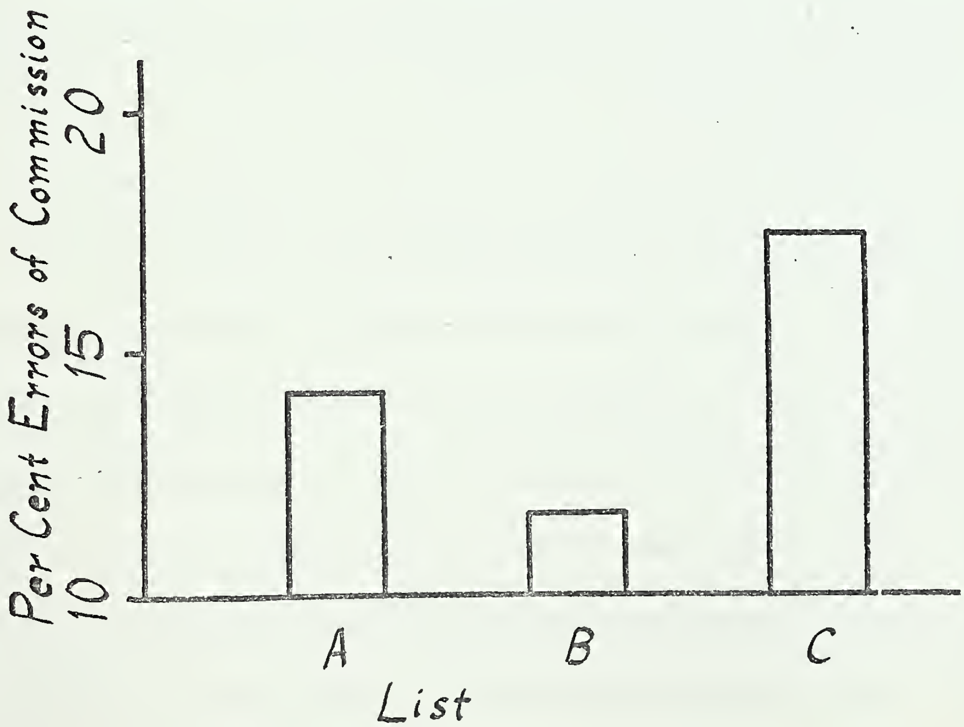

Fig. 17. Mean Per Cent Errors of Commission, by List.

directed to possible effects of the consonant pairs. The major source of information with regard to this subject was Meaningfulness and Verbal Learning (Underwood & Schulz, 1960). These authors reviewed a large number of studies dealing with the effects of high and low meaningfulness of stimulus and response items in verbal learning studies. The great majority of such studies (e.g., Cieutat, Stockwell & Noble, 1958; Kimble & Dufort, 1955; Sheffield, 1946) indicated that differences in meaningfulness of stimulus items produce relatively minor changes in learning rate compared to differences in meaningfulness of response items. In most studies, difficulty in learning associates increased in the direction HH, LH, HL, LL (where "H" refers to high meaningfulness and "L" to low meaningfulness; and where the first letter refers to the stimulus and the second to the response item). This would tend to suggest that the stimulus pairs are an unlikely source of interference with learning--at least, an unlikely source of an effect so powerful as that found in the present study. In view of the well-known fact that elderly people have great difficulty with material of low meaningfulness in general, however, it does not seem unreasonable to look closely at the stimulus items.

Underwood and Schulz included in their book lists of frequencies of single letters and bigrams used in written material in the English language. These authors considered a number of existing lists (including the Thorndike-Lorge list) as well as a study of their own involving 15,000 words. The consonants and consonant pairs used for stimuli in the present study were compared for frequency of usage with the Underwood and Schulz data. Frequency

of use of the single letters is given (here) in ranks; that is, the higher the figure, the lower the frequency of use. For the consonants used in list A, the total of ranks is 247; for list B, 238; for list C, 227. Thus, on the basis of frequency of the single letters, list B obviously does not present a disadvantage. When the consonant pairs are considered, however, something more interesting emerges. Bigram frequencies in the Underwood and Schulz list are given in absolute frequencies rather than in ranks, and the totals for lists A and C appear to be considerably higher than that for list B. Perhaps of even greater importance, lists A and C each contain two bigrams (CJ and MV in list A; XD and HC in list C) which are not given at all in the Underwood and Schulz list. These bigram frequencies are based on a random sample from the Thorndike-Lorge list and on the above-mentioned Underwood list of 15,000 words. Thus, the four bigrams listed above for lists A and C do not appear at all in English among the words which produced the Underwood and Schulz tables. Thus, they would be very low in familiarity and, hence, low in meaningfulness as well. List B contains five such unfamiliar bigrams in a total of eight. Thus, list B contains more than twice the number of stimulus items of low meaningfulness as does either of the other lists.

It seems likely that the stimulus bigrams in list B account for the greater part of the difficulty of this list, even taking into account the fact that low meaningfulness among stimulus items is ordinarily not a source of great variation in learning studies. Fortunately, the counterbalancing built

into the design makes it unnecessary to question other results obtained in the study because of the list effect.

Effects of Order

The following findings resulted from investigation of the variable, "order":

Per Cent Correct Responses, by Order

(N = 45; df = 2, 72--Fig. 18)

	I	II	III	F	p
192 sec.	14.8	15.2	17.5	.70	NS
384 sec.	25.4	30.5	31.1	2.49	NS
576 sec.	33.2	40.2	40.8	4.49	<.025>.01

No significant interactions.

Order does not produce statistically significant differences in means at 192 sec. or at 384 sec. After 576 sec., however, an order effect is apparent. This is to be expected--it is the familiar "practice effect."

Number Correct on Final Learning Trial, by Order

(N = 45, df = 2, 72--Fig. 19)

	I	II	III	F	p
Mean # correct	3.8	5.1	5.0	8.33	< .005

No significant interactions.

Order again produces a statistically significant effect for number of correct responses on the final learning trial of a task Again, this is not unexpected.

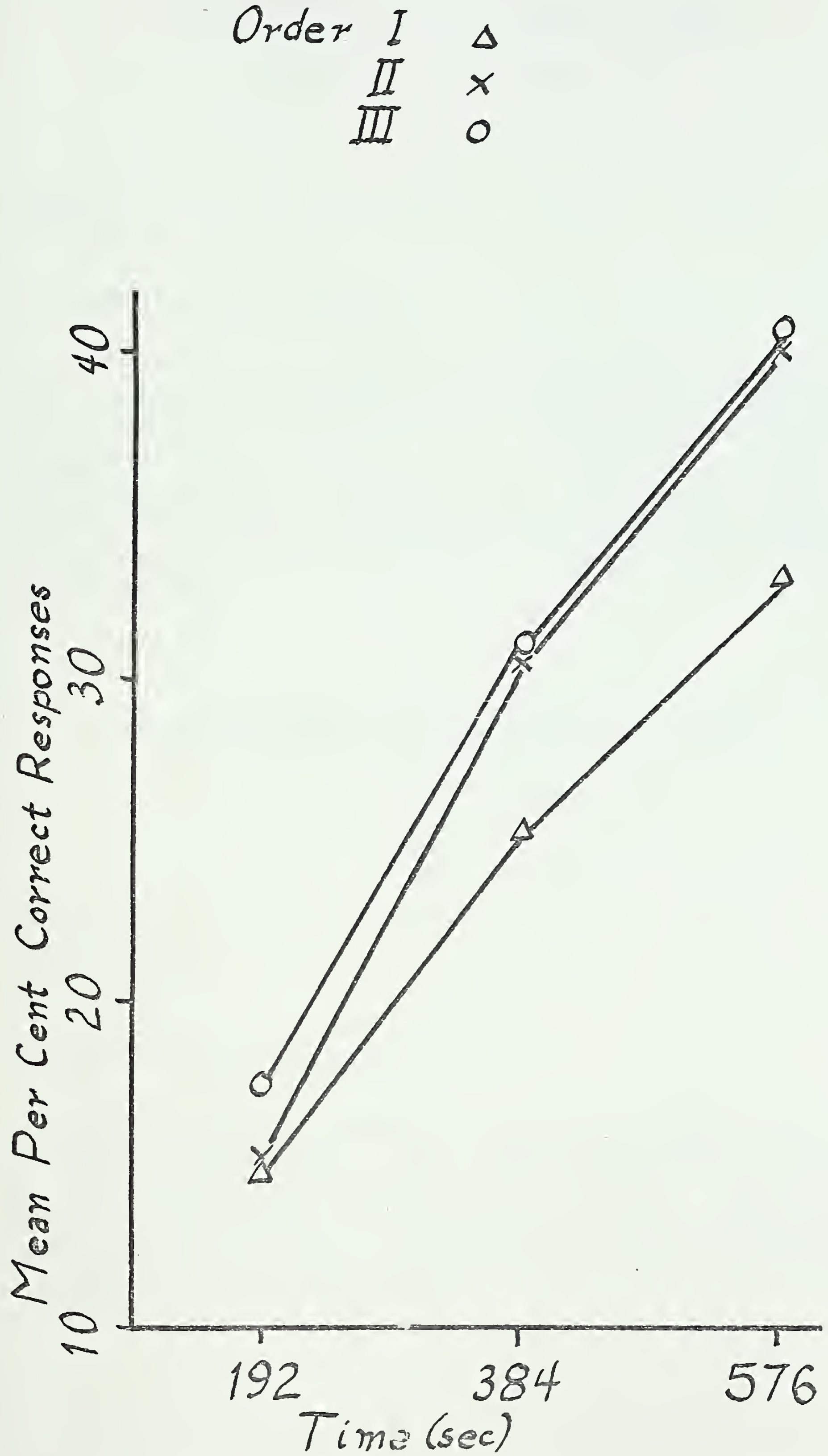

Fig. 18. Mean Per Cent Correct Responses, by Order.

Number Correctly Recalled, by Order

(N = 45; df = 2, 72--Fig. 19)

	I	II	III	F	p
Mean # correct	4.7	5.8	6.1	16.01	< .005

No significant interactions.

As expected, the order effect shows up most strongly on the recall task. Subjects were not informed before the first learning task that they would be required to do the matching task at the end of the learning period; hence, it would be expected that they might do less well the first time this was demanded of them. Inspection of the means shows clearly that there was considerable improvement between tasks I and II, and a much smaller increase in number of correct answers between tasks II and III.

Per Cent Errors of Commission, by Order

(N = 45; df = 2, 72--Fig. 20)

	I	II	III	F	p
Mean % errors of commission	17.3	12.4	13.7	4.16	<.025>.01

No significant interactions.

Order produces a statistically significant effect on the ratio of omission to commission errors. This effect seems to operate in the opposite direction from that of "list," however. Task I, which might be expected to be the most difficult of the three, since it involves learning the task as well as the stimuli, produces the highest percentages of commission errors.

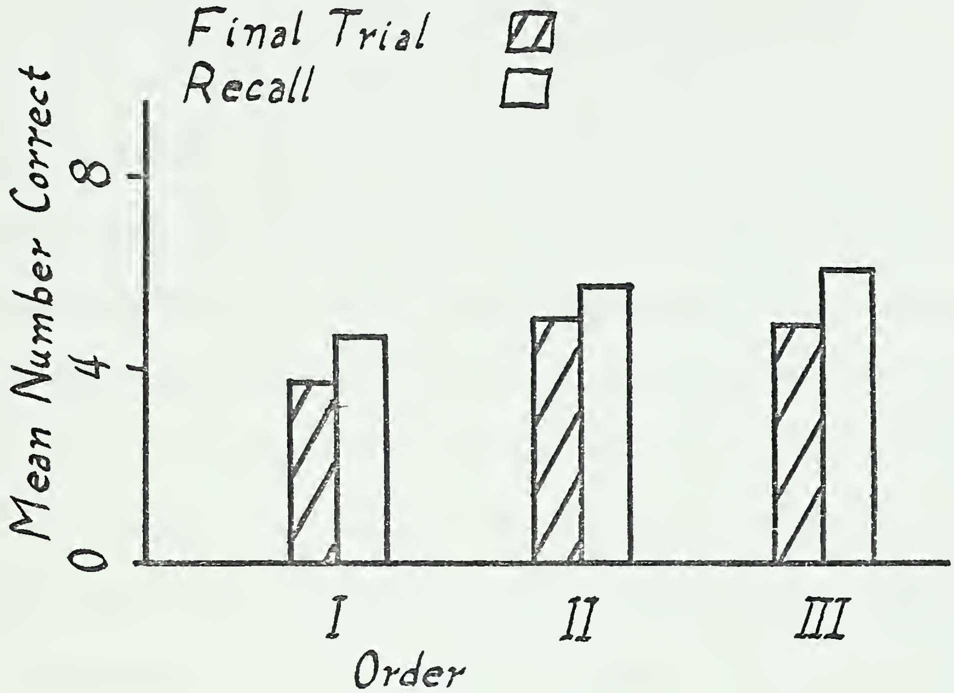

Fig. 19. Mean Correct Responses on Final Learning Trial and on Recall, by Order.

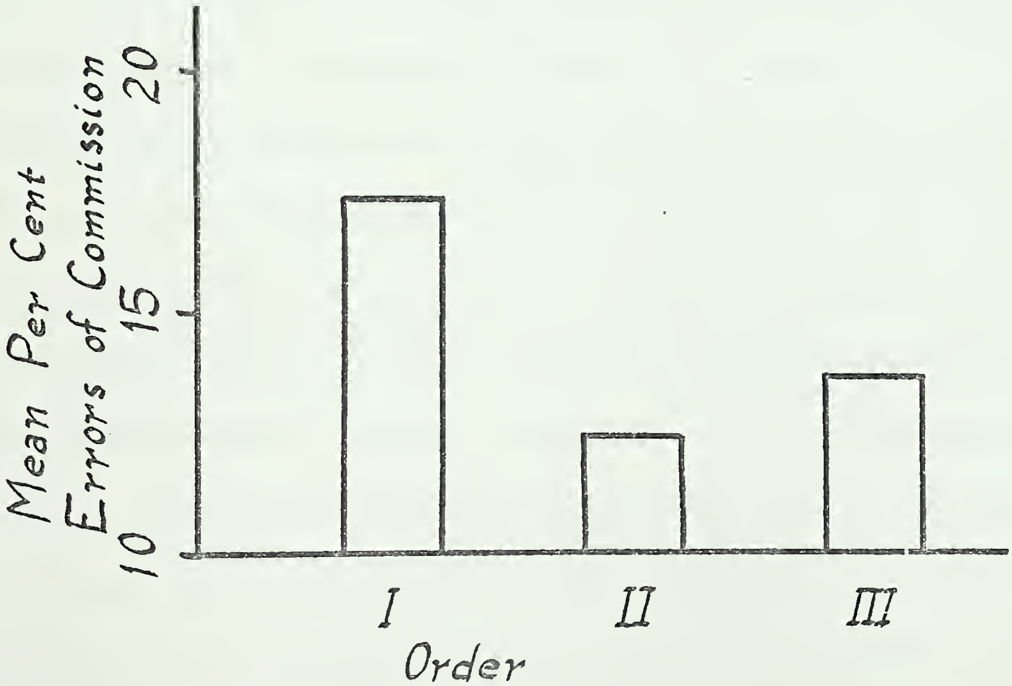

Fig. 20. Mean Per Cent Errors of Commission, by Order.

Discussion

As early as 1938, Lorge, in reanalyzing data from a study on decline of intellectual abilities with age by Jones and Conrad (1933), reported that intellect appeared to decline in these subjects because of the speeded nature of the tasks. Numerous studies have been referred to above, most of them dealing with verbal materials, which show older people to be disadvantaged by the necessity of doing tasks under paced conditions. The same effect appears in many of the studies reported in Welford's book (1958), where the nature of the experimental tasks was quite different. Brown (1957), for example, performed a study which required the subject to plot the position of a ball on a grid. The study had been done previously comparing old and young subjects on accuracy and on time required to complete the task. This time a new, paced condition was added. Subjects learned under both paced and unpaced conditions. In the paced condition, if the subject had not plotted the position of the ball within 8 sec. (a time found comfortable for young subjects in the earlier study but less than the average time required by old subjects), the ball moved to a new position, requiring a new plotting task. Subjects worked for 10 min. at either the paced or unpaced condition and then switched to the other condition. In general, it seemed that there was a severe effect of pacing on subjects in their fifties and over. In addition, however, it was found that old subjects who learned first under the paced condition performed less well under the unpaced condition than did those who

learned without pacing first. Accuracy, as well, fell off under the paced condition. Considering the entire age range covered in this experiment (20-70), performance fell off sharply a full decade earlier under the paced condition.

Welford also reported on the effects of pacing in industry, dividing "paced" tasks into two major categories. In the first, performance was rigidly paced "in the sense that operatives were compelled to keep up with a machine or conveyor-line and to complete each cycle within a fixed average time (1958, p. 114)." In the second category, the pace of work itself was flexible, but there was time pressure in the sense that payment was for piece work. It was found that the mean ages of people working at jobs involving time stress tended to fall, whether the older workers were transferred to different tasks because they were unable to keep up, or because they left of their own accord.

It has frequently been said that older workers often make up for loss of speed by increasing accuracy. With fast pacing, the care required for a high level of accuracy may become too great a burden on the older worker. Welford referred to work of Conrad and Hille (1955) wherein the authors made the point that the time required to complete a given task forms a distribution around the mean. A worker will speed up or slow down his performance from time to time. If the work is stringently paced, however, he will not be able to make up the time lost during his "slow" cycles when he is working faster: "As the time-limit is shortened, or the average time taken

by subjects becomes greater, so more of the 'slow' tail will fall outside of the prescribed limit unless either the subject can in some way speed up the slow cycles, or the pacing is not quite rigid so that a slow time in one cycle can be redeemed by a quick time later."

The present study showed no significant negative effect of fast pacing on a paired associates learning task involving only aged subjects. These conclusions are contrary to what might have been expected from perusal of the literature. In order to explain this, it will be necessary to see how this study differs from others, the results of which were very differently interpreted.

The usual paradigm for a verbal learning study involves presenting material to be learned for a predetermined number of trials or until the subject reaches a predetermined criterion. We also used a criterion as a cut-off point, but found that most of our old subjects did not reach it. In any event, in the usual verbal learning study, it is number of exposures of stimuli that is kept constant. In the present study, the constant is time. In order to see what our results would have been had we used the more common paradigm, we analyzed the results, in terms of number of correct responses, after nine trials at each rate. Nine trials was chosen, of course, because this was the maximum number of trials available under the 2/6 condition. This analysis was done for the 45 old subjects in the full study and for the 10 young subjects in the preliminary study. We cannot, of course, compare these groups statistically with any validity, but we can observe the results,

bearing the differences between groups in mind.

Number Correct Responses after Nine Trials, by Rate (Old)

(N = 45; df = 2, 132--Fig. 21)

	2/2	2/4	2/6	F	p
Mean # correct	15.9	21.8	22.3	2.95	NS

(.05 value for F with df 2, 120 = 3.0718)
(.05 value for F with df 2, ∞ = 2.9957)

Number Correct Responses after Nine Trials, by Rate (Young)

(N = 10; df = 2, 27--Fig. 21)

	2/2	2/4	2/6	F	p
Mean # correct	48.4	48.1	51.5	.34	NS

The F value for old subjects is not statistically significant. However, by inspection of the means we see that rates 2/4 and 2/6 differ very little, while they both show considerable superiority over rate 2/2. Furthermore, noting how low the means are at all rates (there are 64 possible correct responses after nine trials at each rate), we are led to speculate that nine trials are simply not enough for these subjects. The more usual paradigm is likely to involve something on the order of 15 trials. The F value found here closely approaches the 5% level of significance; had there been a larger number of trials, it is probable that we would, indeed, find statistically significant differences.

Considering the young subjects, we find mean numbers of correct responses to be relatively much higher and the F value to be quite low. Here, the pacing seems to have had very little effect. If the means indicate any difference at all, it occurs between rates 2/4 and 2/6 rather than between rates 2/2 and 2/4, as is the case with the older subjects. The higher mean at 2/6 for young subjects, however, is as likely to be a result of greater total time as a result of the duration of the presentation.

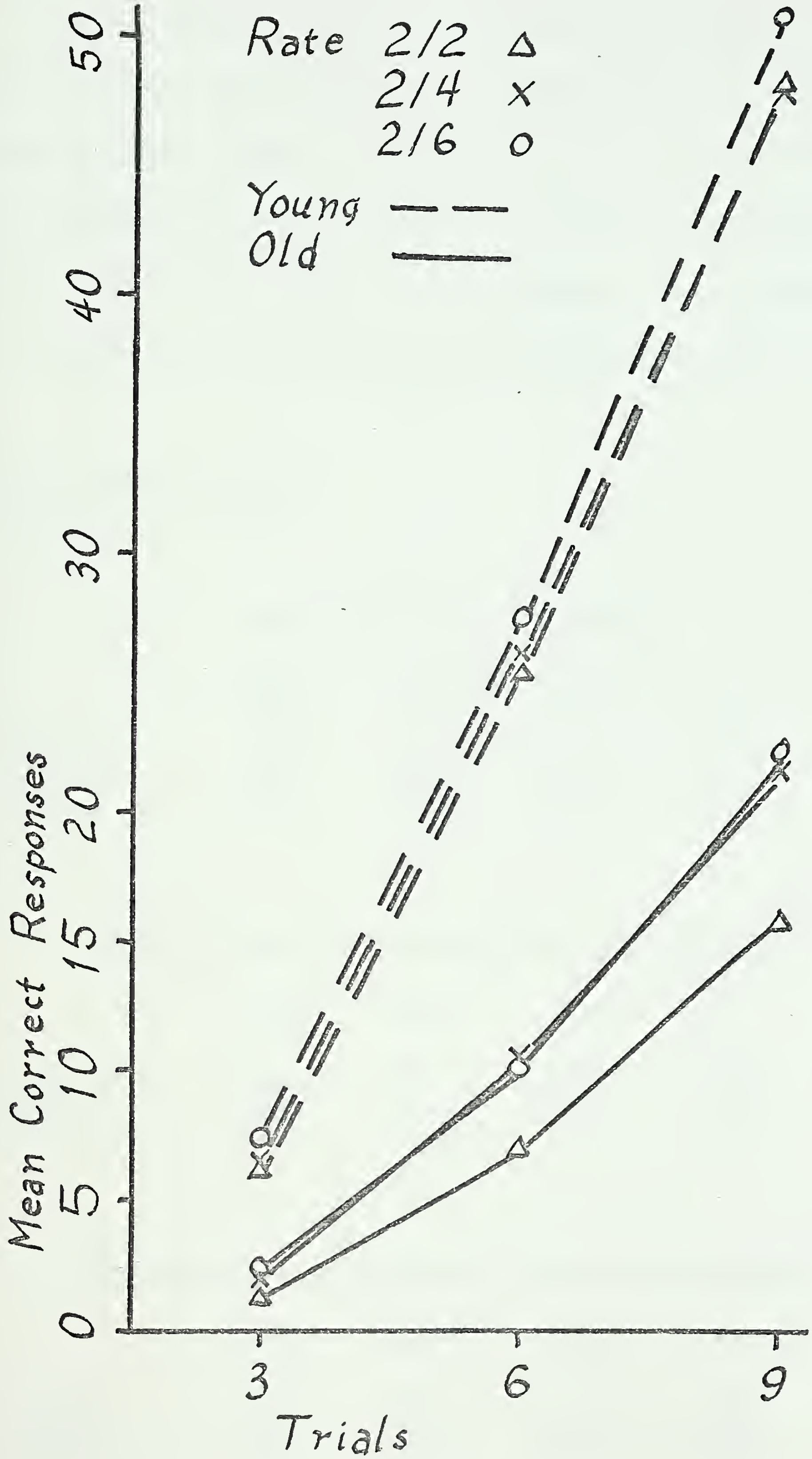

Fig. 21. Mean Correct Responses after Nine Trials, by Rate, for Old and Young Subjects.

The above analysis indicates, then, that if the present study had held trials rather than time constant, as is usually done, our results would be consonant with those which preponderate in the literature. Taking note of this, we will now look more closely at the results of the present study, where time, rather than trials, is held constant. For convenience, we will again present all the results by rate in a single summary.

Summary of Effects of Rate

Per Cent Correct Responses

	2/2	2/4	2/6	F	p
192 sec.	17.9	16.9	12.7	2.55	NS
384 sec.	30.6	31.1	25.3	2.69	NS
576 sec.	39.0	40.5	34.8	2.26	NS

Per Cent Correct Responses--Four Replications

	2/2	2/4	2/6	F	p
192 sec.	21.2	20.1	14.6	1.85	NS
384 sec.	35.6	35.2	28.0	2.64	NS
576 sec.	45.2	45.6	38.1	2.50	NS

Per Cent Correct Responses--Three Replications

	2/2	2/4	2/6	F	p
192 sec.	22.4	21.0	17.2	.97	NS
384 sec.	37.7	36.9	30.7	1.32	NS
576 sec.	48.2	47.2	40.9	.93	NS

Per Cent Correct Responses--Nine Low Subjects

	2/2	2/4	2/6
192 sec.	5.0	4.2	4.9
384 sec.	10.5	14.5	14.4
576 sec.	14.1	20.2	21.5

Per Cent Correct Responses--Eighteen Low Subjects

	2/2	2/4	2/6
192 sec.	11.3	10.9	5.9
384 sec.	20.0	22.3	17.1
576 sec.	25.2	30.6	25.6

Number Correct on Final Learning Trial

2/2	2/4	2/6	F	p
4.6	4.9	4.4	1.21	NS

Number Correct on Recall

2/2	2/4	2/6	F	p
5.4	5.4	5.9	1.72	NS

Per Cent Errors of Commission

2/2	2/4	2/6	F	p
13.2	14.2	15.6	.86	NS

Per Cent Correct Responses on Task I

	2/2	2/4	2/6
192 sec.	18.0	12.8	13.8
384 sec.	28.2	21.4	26.7
576 sec.	35.6	29.2	35.0

Per Cent Correct Responses--WV Scores 12 and Above

	2/2	2/4	2/6
192 sec.	23.2	23.6	18.0
384 sec.	38.3	40.3	32.5
576 sec.	49.1	51.7	42.5

Per Cent Correct Responses--WV Scores 11 and Below

	2/2	2/4	2/6
192 sec.	11.9	9.3	6.6
384 sec.	21.8	20.6	17.0
576 sec.	27.4	27.8	25.9

Mean Time in Seconds to Criterion

2/2	2/4	2/6	F	p
413.3	484.4	537.6	3.54	<.05>.01

Mean Time in Seconds--Criterion Minus One Trial

2/2	2/4	2/6	F	p
381.3	436.4	473.6	2.00	NS

Trials to Criterion

2/2	2/4	2/6	F	p
12.9	10.1	8.4	7.01	$< .005$

Correlations Between WV Score and Per Cent Correct Responses Total

				Total
Rho	.53 $p < .01$	.53 $p < .01$	.48 $p < .01$	.59 $p < .01$
Tau	.39 $p < .05$	.39 $p < .05$	.34 $p < .05$	.43 $p < .05$

Listed above are the mean per cent correct responses by rate for all subjects, for four replications, for three replications, for the nine and eighteen subjects dropped for the last-named two analyses, for performance on Task I, and for subjects with WAIS vocabulary scores 12 and above and 11 and below. In each case, the highest mean for a given analysis is underlined. It will be seen that in no case except for seconds and trials to criterion was a statistically significant effect of rate found. Examining the means, the following trends are suggested:

1. If the learning task had ended at 192 sec., rate 2/2 would show a trend toward superiority overall with only one exception--that for subjects with WAIS vocabulary scores 12 and above. The superiority of rate 2/2 at this point is probably the result of the greater number of exposures of the stimuli.

2. After 384 sec., rate 2/2 produces higher means in four of eight cases, and rate 2/4 in the other four. The differences among means are

generally quite small, and do not seem to fall into any clear-cut pattern that might, for example, suggest differential effects of rate for "good" and "poor" learners.

3. After 576 sec., or at the end of the learning task, rate 2/4 produces the highest means in five cases, rate 2/2 in two cases, and rate 2/6 in one case. Again, the differences among means are often miniscule. The striking fact here is that rate 2/6 produces the best results in only one of 24 cases--that of the nine subjects after 576 sec. Differences between rates 2/2 and 2/4 are usually both so small and so lacking in pattern as to suggest that either of these rates will produce approximately the same results.

4. Rate 2/6 produces a slightly higher number of correct responses on recall, and a slightly higher per cent errors of commission.

The above summary of rate results presents two questions: What can explain the general superiority of rates 2/2 and 2/4; and what can explain the inferiority of rate 2/6? The most obvious difference between the rates which has bearing on this point is the greater number of exposures of the stimuli at the faster speeds. Bearing in mind Conrad and Hille's (1955) remarks with regard to an individual's speed of performance varying about a mean, and particularly their suggestion that slowness at one point may be compensated for at another point when pacing is not rigid, we may venture an analogy. Although it is obvious that a subject who fails to learn a stimulus the first time around (or the second or the third) has effectively "lost" that trial, perhaps repetition (more exposures) can provide the same sort of

redeeming effect one finds where pacing is flexible. This argument is given some credence by the almost-overall superiority of rate 2/2 after 192 sec. At this point, the stimuli had been exposed six times at rate 2/2, four times at rate 2/4, and three times at rate 2/6. If this were the entire explanation, however, we would expect to find the means at rate 2/2 to be twice as large as the means at rate 2/6 at all three points measured. Rate 2/4 "catches up" with rate 2/2 after 384 sec., however, and at no point are the differences among the means strictly proportional to the numbers of exposures. Thus, an interaction between number of stimulus exposures and time *per se* probably takes place.

With regard to the inferiority of rate 2/6, we are reminded of Canestrari's (1965) remarks concerning "momentary lapses of attention" in elderly subjects. Canestrari was, in this context, inferring erasure caused by fresh stimulus input before the previous information has been firmly registered. This would manifestly not be the case here, since the fresh input is arriving more slowly rather than faster. It may be, however, that "momentary lapses of attention" work in the opposite direction as well--that the subject may experience such lapses when the time is too long as well as when it is too short. A subject staring for six seconds at a slide bearing two consonants, a dash and a two-syllable word might become, in effect, so bored that his attention wanders to something more interesting. This might occur especially in those subjects who are having difficulty with the task in general, and who feel that there is little point in trying. For "good"

learners, the 6-sec. rate might result in a great deal of "dead" time with no learning occurring. These subjects, however, might have already learned a goodly proportion of the material and might be able to hold it in memory even while their attention wandered. It will be remembered that all responses take place during the 2-sec. stimulus time (rather than the variable stimulus-response time). This period is short enough, and the demands of the task definite enough, for attention to be less likely to be diverted here. Canestrari referred to a hypothetical and randomly distributed attention lapse. We are considering the possibility of a different sort of lapse of attention which is directly related to the long exposure rate. The effect, however, would seem similar.

Considering, then, the work already in the literature regarding the negative effects of fast pacing for older subjects, and the information gleaned from the present experiment, it appears that fast pacing does provide a disadvantage under certain, but not all, conditions. If pacing is fast and rigid and there is no opportunity to make up for information "lost" during a trial wherein the subject has not grasped it, then his performance suffers. If, however, total time for different rates is held constant, the subject has opportunities to redeem his losses. Conversely, when pacing is slow (with the time allowed for responses held constant), the subject has fewer opportunities--fewer exposures of the material to be learned--to make up for what he misses the first few times around. He also has more "dead" time. The 6 sec. available for learning a particular pair is valuable only until that

pair has been learned. Once this has occurred, the subject may spend the extra time in rehearsal of the material which is as yet imperfectly learned. The present data suggest, however, that either this is not the way the time is used or that the attempt is unsuccessful. Probably both circumstances occur.

There are a few studies scattered throughout the literature on pacing and performance in older people which suggest, as does the present study, that fast pacing does not necessarily place these subjects at a disproportionate disadvantage. For example, Heron and Chown (1967) reported that older subjects in a test of dynamic visual acuity do not find the faster speeds relatively more difficult than the slower speeds. Griew (1959), in a reaction time study, found that when the signal was given for a very short time, the older person's reaction time was improved whereas that of the younger person was unchanged. Griew felt that this finding indicated that older people can react quickly when they must. Semeonoff and Trist (1958) gave the Progressive Matrices with a 20-min. and a 40-min. time limit and reported that men over 45 "appeared to make relatively better use of the time allowed than younger ones." Semeonoff and Trist were dealing with only high IQ subjects and had few subjects over 45, and these factors must be taken into account in interpreting their data. Heron and Chown, however, gave the Progressive Matrices under similar conditions and found similar results. Heron and Chown did not inform their subjects that time was a consideration--rather, they allowed 40 min. for each subject to complete the

test, but made note of the score after 20 min. as well as after 40 min. They reported a product-moment correlation of .92 between 20-min. and 40-min. scores, and reported that older subjects seemed to make less use of the extra 20 min. than did younger ones. Heron and Chown stated that their findings suggested that

> . . . the effect on the old of an imposed but unmentioned time limit may not be a universal one of penalty, nor as drastic as people have commonly suggested. Nevertheless, at most levels of "power" there is a distinct likelihood that older people will make larger gains in extra time than will younger ones. . . . and would be underestimated by the twenty minute test given with "untimed" instructions.

In a digit coding task, the same authors gave the test with both timed and untimed instructions. There was a high correlation between methods (r = .898 for males and .927 for females). Even so, a "small but significant" negative correlation remained between speeded performance and age when unspeeded performance was held constant through statistical manipulation. The authors say that older people do relatively less well than do younger ones under instructions to work as quickly as possible compared with instructions which do not emphasize speed. These findings suggest to the present writer that the awareness of the need to work quickly may well be as important a factor in the older person's relatively poorer performance under such conditions as the pacing itself.

All the above findings seem to direct our attention to the concept of task difficulty. It will be remembered that Szafran (1963) found that performance among his older pilots deteriorated only under conditions of

"information overload," and that Welford (1958) reported that age differences show up in situations which require alternation between taking in information for retention and recalling information for the making of responses. Talland (1968) reported that "demanding operations of discrimination and choice" put the aged at a disadvantage. It has frequently been suggested that the disadvantage for aged subjects is increased as the performances required of them become more complex.

Birren (1964), in discussing old and young subjects, reported, "Generally, the young adult, who has a large capacity for the rapid intake of information, is limited largely by differential familiarity or practice. He is fast or slow depending on the difficulty of the material he is dealing with." Birren goes on to say that a general quality of slowness appears among older people which is unrelated to differential practice or familiarity. We do not question this generalized slowing, but suggest that the same effect of task difficulty, whether from lack of familiarity with the material or from increased complexity of the task, or from other sources, may not only have the same effect upon older as upon younger subjects, but that the older subjects may be differentially affected by increasing task difficulty. The notion of familiarity with the materials may be especially important here, since the typical older subject is much farther in time from practice with such tasks as are usual in laboratory studies than the typical younger subject--usually a college student.

Heron and Chown (1967) used Reitan's Trail-Making Test as a part of

their battery. They found that "Performance in the "alternation" letter and number half of the test declines more with age than in the first half for which the subject only has to connect numbers in sequence." This seems to be a clear case of task difficulty (or complexity) producing a relatively greater negative effect upon performance. The Trail-Making Test is, of course, timed; and the subject is requested to complete the task as quickly as possible. The final score is derived from the times taken for the two halves of the test. As Heron and Chown found, the more complex second half contributed disproportionately to lower scores (longer time) for older subjects.

Birren (1964) reported other findings which may have relevance to task difficulty. For example, he stated that older persons were more affected by the introduction of irrelevant materials than were young adults. Later, he stated, ". . . it would be expected that old and young individuals will differ more in the speed of complex than of simple tasks." In reporting the results of a study on addition and subtraction wherein subjects completed either addition or subtraction problems, or were required to alternate between the two, he said, "While these results seem to indicate that adults over the age of sixty-five show less facility in alternating tasks rapidly, the age difference in speed of alternating was less than the difference in speed associated with task difficulty (in this case, problem length)."

The results of the present study indicate that the effects of fast pacing may not always be negative, and that the total amount of time involved in a particular learning task is an additional variable which must be taken into

account. The data further suggest that a slow pace is not necessarily better; in these data, the slowest pace generally produces the poorest performance. We suggest that fast pacing (and, especially, the awareness of the need for speed) may reflect not only the effects of generalized slowing in an aging organism, but may also be one of a number of variables which might all be subsumed under the broader concept of task difficulty. Fast pacing in verbal learning tasks has been demonstrated (in the many studies reported above as well as in the present comparison of performance at different rates with number of exposures held constant) to increase the difficulty of the task to a disproportionate degree among aged persons. With time held constant, however, the present data would tend to suggest that the repetition involved in the greater number of stimulus exposures at the faster rates cancels out the effect of fast pacing itself. Furthermore, a slow pace (in the present study), even though it is a pace within the range utilized in many previous experiments, does not necessarily provide an advantage when another variable, time, is held constant. We suggest, therefore, that the effects of pacing might well be re-examined with attention directed to time, complexity of the task(s), and other factors (e.g., meaningfulness of the material; familiarity with the type of task, practice) which contribute to the general category of difficulty.

APPENDIXES

Appendix I

SAMPLE SCORING SHEETS

A

ORDER ABC

RATE 2:2

NAME

DATE

one trial

1 CJ - WOMAN
2 DL - ROBIN
3 KB - PERSON
4 XH - SEVEN
5 MV - ORDER
6 SQ - HUMOR
7 NF - DOCTOR
8 TZ - NATION
9 MV - ORDER
10 KB - PERSON
11 DL - ROBIN
12 CJ - WOMAN
13 SQ - HUMOR
14 TZ - NATION
15 XH - ORDER
16 NF - DOCTOR
17 TZ - NATION
18 SQ - HUMOR
19 KB - PERSON
20 XH - SEVEN
21 CJ - WOMAN
22 MV - ORDER
23 DL - ROBIN
24 NF - DOCTOR
25 TZ - NATION
26 KB - PERSON
27 CJ - WOMAN
28 NF - DOCTOR
29 DL - ROBIN
30 XH - SEVEN
31 SQ - HUMOR
32 MV - ORDER
33 CJ - WOMAN
34 TZ - NATION
35 DL - ROBIN
36 MV - ORDER
37 NF - DOCTOR
38 XH - SEVEN
39 SQ - HUMOR
40 KB - PERSON

6 trials
192"

A 2

ORDER ABC

DATE 2:2

NAME

DATE

1 CJ - WOMAN ______ ______
2 DL - ROBIN ______ ______
3 KB - PERSON ______ ______
4 XH - SEVEN ______ ______
5 MV - ORDER ______ ______
6 SQ - HUMOR ______ ______
7 NF - DOCTOR ______ ______
8 TZ - NATION ______ ______
9 MV - ORDER ______ ______
10 KB - PERSON ______ ______
11 DL - ROBIN ______ ______
12 CJ - WOMAN ______ ______
13 SQ - HUMOR ______ ______
14 TZ - NATION ______ ______
15 XH - ORDER ______ ______
16 NF - DOCTOR ______ ______
17 TZ - NATION ______ ______
18 SQ - HUMOR ______ ______
19 KB - PERSON ______ ______
20 XH - SEVEN ______ ______
21 CJ - WOMAN ______ ______
22 MV - ORDER ______ ______
23 DL - ROBIN ______ ______
24 NF - DOCTOR ______ ______ 18 trials
25 TZ - NATION ______ ______ 576"
26 KB - PERSON ______ ______
27 CJ - WOMAN ______ ______
28 NF - DOCTOR ______ ______
29 DL - ROBIN ______ ______
30 XH - SEVEN ______ ______
31 SQ - HUMOR ______ ______
32 MV - ORDER ______ ______
33 CJ - WOMAN ______ ______
34 TZ - NATION ______ ______
35 DL - ROBIN ______ ______
36 MV - ORDER ______ ______
37 NF - DOCTOR ______ ______
38 XH - SEVEN ______ ______
39 SQ - HUMOR ______ ______
40 KB - PERSON ______ ______

576" = one learning task

B

ORDER A$\underline{B}$C RATE 2:4

NAME DATE

one trial

1 DS - HONEY
2 FC - VISIT
3 TO - NOVEL
4 MW - OBJECT
5 PB - STUDY
6 KZ - SECOND
7 RJ - FIGURE
8 NH - FAVOR
9 PB - STUDY
10 TO - NOVEL
11 FC - VISIT
12 DS - HONEY
13 KZ - SECOND
14 NH - FAVOR
15 MW - OBJECT
16 RJ - FIGURE
17 NH - FAVOR
18 KZ - SECOND
19 TO - NOVEL
20 MW - OBJECT
21 DS - HONEY
22 PB - STUDY
23 FC - VISIT
24 RJ - FIGURE
25 NH - FAVOR
26 TO - NOVEL
27 DS - HONEY
28 RJ - FIGURE
29 FC - VISIT
30 MW - OBJECT
31 KZ - SECOND
32 PB - STUDY
33 DS - HONEY
34 NH - FAVOR
35 FC - VISIT
36 PB - STUDY
37 RJ - FIGURE
38 MW - OBJECT
39 KZ - SECOND
40 TO - NOVEL

8 trials
384"

B 2

ORDER A<u>B</u>C

RATE 2:4

NAME

DATE

1 DS - HONEY
2 FC - VISIT
3 TO - NOVEL
4 MW - OBJECT
5 PB - STUDY
6 KZ - SECOND
7 RJ - FIGURE
8 NH - FAVOR

9 PB - STUDY
10 TO - NOVEL
11 FC - VISIT
12 DS - HONEY
13 KZ - SECOND
14 NH - FAVOR
15 MW - OBJECT
16 RJ - FIGURE

17 NH - FAVOR
18 KZ - SECOND
19 TO - NOVEL
20 MW - OBJECT
21 DS - HONEY
22 PB - STUDY
23 FC - VISIT
24 RJ - FIGURE

25 NH - FAVOR
26 TO - NOVEL
27 DS - HONEY
28 RJ - FIGURE
29 FC - VISIT
30 MW - OBJECT
31 KZ - SECOND
32 PB - STUDY

33 DS - HONEY
34 NH - FAVOR
35 FC - VISIT
36 PB - STUDY
37 RJ - FIGURE
38 MW - OBJECT
39 KZ - SECOND
40 TO - NOVEL

C

ORDER ABC

RATE 2:6

NAME

DATE

one trial

1 XD - JEWEL
2 GS - UNCLE
3 LF - PAPER
4 NR - OCEAN
5 SP - HONOR
6 HC - SISTER
7 WK - FINISH
8 BJ - REPORT

6 trials 384"

9 SP - HONOR
10 LF - PAPER
11 GS - UNCLE
12 XD- JEWEL
13 HC - SISTER
14 BJ - REPORT
15 NR - OCEAN
16 WK - FINISH
17 BJ - REPORT
18 HC - SISTER
19 LF - PAPER
20 NR - OCEAN
21 XD - JEWEL
22 SP - HONOR
23 GS - UNCLE
24 WK - FINISH
25 BJ - REPORT
26 LF - PAPER
27 XD - JEWEL
28 WK - FINISH
29 GS - UNCLE
30 NR - OCEAN
31 HC - SISTER
32 SP - HONOR

9 trials 576"

33 XD- JEWEL
34 BJ - REPORT
35 GS - UNCLE
36 SP - HONOR
37 WK - FINISH
38 NR - OCEAN
39 HC- SISTER
40 LF - PAPER

Sample Summary Sheet

	192"	384"	576"
Trials			
# Corr			
% Corr			
Order			
Trials			
# Corr			
% Corr			
Order			
Trials			
# Corr			
% Corr			
Order			

Learning	# Corr	Poss	%	Time Cr	Trials Cr
1					
2					
3					

% Corr at 576" by Order

I

II

III

% Corr Final Trial

% Corr at 576" by Rate

2:2

2:4

2:6

Errors

	2:2	2:4	2:6
C			
O	___	___	___
T	___	___	___
% C			
% O			

% Corr at 576" by List

A

B

C

% Corr Recall

Appendix II

STATISTICAL ANALYSES

Analysis of Variance for Full Study (N = 45)

Variable 192 Sec.

Source of Variation	df	SS	MS	F
Blocks (confounded treatments)	8	1934.88	241.36	.50
Order X List	2	236.62	118.31	.24
Order X Rate	2	664.06	332.03	.68
List X Rate	2	424.93	212.46	.44
Order X List X Rate	2	609.27	304.64	.62
Subjects within blocks	36	17568.00	488.00	3.50
Total between subjects	44	19502.88	443.25	3.18
Treatments (unconfounded)	18	4959.49	275.53	1.97
Order	2	196.20	98.10	.70
List	2	1663.58	831.79	5.96***
Order X List	2	112.68	56.34	.40
Rate	2	711.58	355.79	2.55
Order X Rate	2	4.20	2.10	.02
List X Rate	2	406.10	203.05	1.46
Order X List X Rate	6	1865.15	310.86	2.23
Treatments X Subjects in blocks (error)	72	10045.31	139.52	
Total within subjects	90	15004.80	166.72	
Total	134	34507.68		

*Significant beyond the 5% level of probability.

**Significant beyond the 1% level of probability.

***Significant beyond the .5% level of probability.

Analysis of Variance for Full Study (continued)

Variable 384 Sec.

Source of Variation	df	SS	MS	F
Blocks (confounded treatments)	8	4534.19	544.27	.58
Order X List	2	1144.73	572.36	.61
Order X Rate	2	1877.00	938.80	1.01
List X Rate	2	458.99	229.50	.25
Order X List X Rate	2	872.87	436.44	.47
Subjects within blocks	36	33598.80	933.30	5.37
Total between subjects	44	37952.99	862.57	4.97
Treatments (unconfounded)	18	9532.26	529.57	3.05
Order	2	863.81	431.90	2.49*
List	2	5981.94	2996.97	17.22***
Order X List	2	102.09	51.04	.29
Rate	2	934.62	467.31	2.69
Order X Rate	2	107.89	53.94	.31
List X Rate	2	130.40	65.20	.38
Order X List X Rate	6	1411.51	235.25	1.35
Treatments X Subjects in blocks (error)	72	12506.94	173.71	
Total within subjects	90	22039.20	244.88	
Total	134	59992.19	447.70	

*Significant beyond the 5% level of probability.

**Significant beyond the 1% level of probability.

***Significant beyond the .5% level of probability.

Analysis of Variance for Full Study (continued)

Variable 576 Sec.

Source of Variation	df	SS	MS	F
Blocks (confounded treatments)	8	4818.00	602.25	.44
Order X List	2	1280.33	640.16	.47
Order X Rate	2	2338.20	1169.10	.85
List X Rate	2	372.99	186.50	.14
Order X List X Rate	2	826.47	413.24	.30
Subjects within blocks	36	49557.59	1376.60	7.72
Total between subjects	44	54375.59	1235.81	6.93
Treatments (unconfounded)	18	11183.42	621.30	3.48
Order	2	1604.67	802.33	4.49*
List	2	7279.26	3639.63	20.41***
Order X List	2	25.37	12.68	.07
Rate	2	805.24	402.62	2.26
Order X Rate	2	87.02	43.51	.24
List X Rate	2	64.79	32.39	.18
Order X List X Rate	6	1317.07	219.51	1.23
Treatments X Subjects in blocks (error)	72	12758.38	178.32	
Total within subjects	90	23941.80	266.92	
Total	134	78317.39	585.06	

*Significant beyond the 5% level of probability.

**Significant beyond the 1% level of probability.

***Significant beyond the .5% level of probability.

Analysis of Variance for Full Study (continued)

Variable Recall

Source of Variation	df	SS	MS	F
Blocks (confounded treatments)	8	11958.28	1494.79	.55
Order X List	2	48.61	24.31	.01
Order X Rate	2	3298.60	1649.30	.60
List X Rate	2	3270.80	1635.40	.59
Order X List X Rate	2	5340.27	2670.14	.98
Subjects within blocks	36	98144.50	2727.40	10.63
Total between subjects	44	110144.68	2503.29	9.75
Treatments (unconfounded)	18	14438.60	802.14	3.13
Order	2	8216.00	4108.00	16.01***
List	2	3174.55	1587.28	6.18***
Order X List	2	187.45	93.73	.37
Rate	2	881.61	440.81	1.72
Order X Rate	2	272.07	136.04	.53
List X Rate	2	549.97	274.99	1.07
Order X List X Rate	6	1156.95	192.83	.75
Treatments X Subjects in blocks (error)	72	18478.00	256.64	
Total within subjects	90	32916.60	365.74	
Total	134	143061.28	1067.62	

*Significant beyond the 5% level of probability.

**Significant beyond the 1% level of probability.

***Significant beyond the .5% level of probability.

Analysis of Variance for Full Study (continued)

Variable Correct Final Trial

Source of Variation	df	SS	MS	F
Blocks (confounded treatments)	8	5606.45	700.81	.25
Order X List	2	1446.73	723.36	.26
Order X Rate	2	2988.40	1494.20	.54
List X Rate	2	1085.67	542.84	.19
Order X List X Rate	2	85.65	42.82	.02
Subjects within blocks	36	100144.80	2781.80	6.69
Total between subjects	44	105751.25	2403.44	5.78
Treatments (unconfounded)	18	22376.74	1243.15	2.99
Order	2	6920.13	3460.07	8.33***
List	2	9837.62	4918.81	11.84***
Order X List	2	363.92	181.96	.44
Rate	2	1009.18	504.59	1.21
Order X Rate	2	169.86	84.93	.20
List X Rate	2	1072.43	536.22	1.29
Order X List X Rate	6	3003.60	500.60	1.20
Treatments X Subjects in blocks (error)	72	29915.06	415.49	
Total within subjects	90	52291.80	581.02	
Total	134	158043.09	1179.42	

*Significant beyond the 5% level of probability.

**Significant beyond the 1% level of probability.

***Significant beyond the .5% level of probability.

Analysis of Variance for Full Study (continued)

Variable Errors of Commission

Source of Variation	df	SS	MS	F
Blocks (confounded treatments)	8	1608.38	201.50	.68
Order X List	2	3.51	1.76	.006
Order X Rate	2	449.87	224.94	.76
List X Rate	2	607.92	303.96	1.03
Order X List X Rate	2	547.08	273.54	.92
Subjects within blocks	36	10635.48	295.43	3.89
Total between subjects	44	12243.86	278.27	3.65
Treatments (unconfounded)	18	2126.55	118.14	1.55
Order	2	633.08	316.54	4.16*
List	2	737.56	368.78	4.84*
Order X List	2	95.93	47.96	.63
Rate	2	131.39	65.70	.86
Order X Rate	2	26.57	13.28	.17
List X Rate	2	144.56	72.28	.95
Order X List X Rate	6	357.46	59.58	.78
Treatments X Subjects in blocks (error)	72	5484.39	76.17	
Total within subjects	90	7610.94	84.57	
Total	134	19854.80	148.17	

*Significant beyond the 5% level of probability.

**Significant beyond the 1% level of probability.

***Significant beyond the .5% level of probability.

Analysis of Variance for Four Replications (N = 36)

Variable 192 Sec.

Source of Variation	df	SS	MS	F
Between subjects	35	14178.76	405.11	2.25
Treatments				
Order	2	162.41	81.20	.45
List	2	1901.08	950.54	5.27*
Rate	2	666.31	333.16	1.85
Error and interaction	66	11903.34	180.35	
Total within subjects	72	14633.14	203.24	
Total	107	28811.90	269.27	

Variable 384 Sec.

Source of Variation	df	SS	MS	F
Between subjects	35	23599.79	674.28	3.51
Treatments				
Order	2	1156.71	578.36	3.01
List	2	5627.78	3263.89	16.99***
Rate	2	1015.63	507.82	2.64
Error and interaction	66	12679.55	192.11	
Total within subjects	72	21379.67	296.93	
Total	107	44979.46	420.37	

*Significant beyond the 5% level of probability.
**Significant beyond the 1% level of probability.
***Significant beyond the .5% level of probability.

Analysis of Variance for Four Replications (continued)

Variable 576 Sec.

Source of Variation	df	SS	MS	F
Between subjects	35	32058.06	915.94	5.15
Treatments				
Order	2	2054.96	1027.48	5.77**
List	2	7810.43	3905.22	21.94***
Rate	2	888.64	444.32	2.50
Error and interaction	66	11746.84	177.98	
Total within subjects	72	22500.87	312.51	
Total	107	54558.93	509.90	

Variable Recall

Source of Variation	df	SS	MS	F
Between subjects	35	57237.54	1635.36	6.97
Treatments				
Order	2	9212.96	4606.48	19.62***
List	2	4490.74	2245.37	9.56***
Rate	2	384.84	192.42	.82
Error and interaction	66	15493.48	234.75	
Total within subjects	72	29582.02	410.86	
Total	107	86819.56	811.40	

*Significant beyond the 5% level of probability.
**Significant beyond the 1% level of probability.
***Significant beyond the .5% level of probability.

Analysis of Variance for Four Replications (continued)

Variable Correct Final Trial

Source of Variation	df	SS	MS	F
Between subjects	35	60975.91	1742.17	4.13
Treatments				
Order	2	7604.17	3802.08	9.02***
List	2	9557.29	4778.64	11.33***
Rate	2	1050.35	525.18	1.25
Error and interaction	66	27827.84	421.63	
Total within subjects	72	46039.65	639.44	
Total	107	107015.56	1000.14	

Variable Errors of Commission

Source of Variation	df	SS	MS	F
Between subjects	35	10245.19	292.72	3.34
Treatments				
Order	2	561.38	280.69	3.20
List	2	868.45	432.22	4.93*
Rate	2	102.41	51.20	.58
Error and interaction	66	5786.18	87.67	
Total within subjects	72	7318.42	101.64	
Total	107	17563.61	164.14	

*Significant beyond the 5% level of probability.
**Significant beyond the 1% level of probability.
***Significant beyond the .5% level of probability.

Analysis of Variance for Three Replications (N = 27)

Variable 192 Sec.

Source of Variation	df	SS	MS	F
Between subjects	26	8441.02	324.65	1.45
Treatments				
Order	2	102.16	51.08	.23
List	2	1760.46	880.23	3.95*
Rate	2	432.57	216.28	.97
Error and interaction	48	10705.75	223.04	
Total within subjects	54	13000.93	240.76	
Total	80	21441.95	268.02	

Variable 384 Sec.

Source of Variation	df	SS	MS	F
Between subjects	26	11418.94	439.19	1.95
Treatments				
Order	2	886.83	443.41	1.97
List	2	5453.02	2726.51	12.09***
Rate	2	593.47	296.74	1.32
Error and interaction	48	10827.45	225.57	
Total within subjects	54	17760.77		
Total	80	29179.71		

*Significant beyond the 5% level of probability.
**Significant beyond the 1% level of probability.
***Significant beyond the .5% level of probability.

Analysis of Variance for Three Replications (continued)

Variable 576 Sec.

Source of Variation	df	SS	MS	F
Between subjects	26	14137.09	543.73	2.89
Treatments				
Order	2	1246.11	623.06	3.32
List	2	5906.73	2953.36	15.72***
Rate	2	348.40	174.20	.93
Error and interaction	48	9016.59	187.85	
Total within subjects	54	16517.84	305.89	
Total	80	30654.93	383.19	

Variable Recall

Source of Variation	df	SS	MS	F
Between subjects	26	19201.36	738.51	3.57
Treatments				
Order	2	7812.50	3906.25	18.86***
List	2	1990.74	995.37	4.81*
Rate	2	150.46	75.23	.36
Error and interaction	48	9941.87	207.12	
Total within subjects	54	19895.57	368.44	
Total	80	39096.93	488.71	

*Significant beyond the 5% level of probability.
**Significant beyond the 1% level of probability.
***Significant beyond the .5% level of probability.

Analysis of Variance for Three Replications (continued)

Variable Correct Final Trial

Source of Variation	df	SS	MS	F
Between subjects	26	23680.50	275.53	3.24
Treatments				
Order	2	4664.35	2332.18	6.04**
List	2	4826.39	2413.19	6.25**
Rate	2	312.50	156.25	.40
Error and interaction	48	18529.88	386.04	
Total within subjects	54	28333.12	524.69	
Total	80	52013.62	650.17	

Variable Errors of Commission

Source of Variation	df	SS	MS	F
Between subjects	26	7163.84	275.53	3.24
Treatments				
Order	2	456.91	228.46	2.69
List	2	546.74	273.37	3.22
Rate	2	95.43	47.72	.56
Error and interaction	48	4078.99	84.98	
Total within subjects	54	5178.08	95.89	
Total	80	12341.92	154.27	

*Significant beyond the 5% level of probability.
**Significant beyond the 1% level of probability.
***Significant beyond the .5% level of probability.

Analysis of Variance--Seconds to Criterion by Rate

(T = 28; N = 12, 11, 5)

Source of Variation	df	SS	MS	F
Between subjects	2	62442.44	31221.22	3.54*
Within subjects	25	219916.42	8796.65	
Total	27	282358.86		

Analysis of Variance--Seconds to Criterion by Rate, Minus One Trial

(T = 28; N = 12, 11, 5)

Source of Variation	df	SS	MS	F
Between subjects	2	35242.44	17621.22	2.00
Within subjects	25	219916.42	8796.65	
Total	27	255158.86		

*Significant beyond the 5% level of probability.

**Significant beyond the 1% level of probability.

***Significant beyond the .5% level of probability.

Analysis of Variance--Trials to Criterion by Rate

(T = 28; N = 12, 11, 5)

Source of Variation	df	SS	MS	F
Between subjects	2	86.97	43.48	7.01***
Within subjects	25	155.03	6.20	
Total	27	242.00		

Analysis of Variance--Correct Responses after Nine Trials, by Rate

(Old Subjects--N = 45)

Source of Variation	df	SS	MS	F
Between subjects	2	1125.75	562.87	2.95
Within subjects	132	25181.25	190.76	
Total	134	26307.00		

*Significant beyond the 5% level of probability.

**Significant beyond the 1% level of probability.

***Significant beyond the .5% level of probability.

Analysis of Variance--Correct Responses after Nine Trials, by Rate

(Young Subjects--N = 10)

Source of Variation	df	SS	MS	F
Between subjects	2	70.87	35.43	.34
Within subjects	27	2743.80	101.62	
Total	29	2814.67		

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